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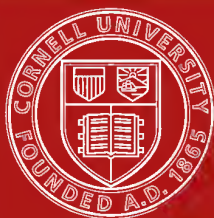
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EXPERIMENTAL STUDIES IN PSYCHOLOGY AND PEDAGOGY

EDITED BY LIGHTNER WITMER

*DEPARTMENT OF SPECIAL PUBLICATION*

II. THE SENSATION OF PAIN AND THE THEORY  
OF THE SPECIFIC SENSE ENERGIES

THE SENSATION OF PAIN AND THE  
THEORY OF THE SPECIFIC  
SENSE ENERGIES

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## PREFATORY NOTE

THIS monograph continues the Experimental Studies in Psychology and Pedagogy, the initial number appearing simultaneously under the title of *Spelling in the Elementary Schools: an Experimental and Statistical Investigation*.

LIGHTNER WITMER.

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## PREFACE

THIS monograph is the outgrowth of an experimental investigation begun in the psychological laboratory of the University of Pennsylvania in 1897 and continued at irregular intervals during the two following years. In 1900 it was presented substantially in its present form to the Faculty of the Department of Philosophy in the University of Pennsylvania and accepted as a thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

The experiments were directed, at first, exclusively to the investigation of local differences in the sensitivity of cutaneous areas; it was assumed that such differences, if found, would furnish conclusive evidence of the existence of a distinct terminal apparatus for pain. As the investigation progressed, however, it became evident that it was necessary to subject this point of view itself to a critical and experimental examination, if the results were to be given an adequate interpretation.

The first step in this examination led to the question, "How do the several parts in a nexus of processes — connected with stimulus, sense organ or brain, and psychosis — present themselves as material for investigation?" It is commonly assumed that physical, physiological, and psychical processes are discretely and directly open to investigation. A little reflection will show the error of such an assumption. A pain stimulus that can be studied without reference to the pain process it excites in a sense organ, a pain organ to be investigated without reference to the pain sensation, a pain psychosis pure and simple to be studied apart from the subject's judgment or bodily reaction, — these are accessible to no experimental method. In even the simplest experiment it is impossible to deal separately with any one of the three parts of the total psychophysical process.

The experimenter has direct knowledge of but two things: the stimulation and the reaction. What occurs between the two he does not know, and any statements he may make regarding it are inferences based upon the subject's reaction. In other words, he has but the two terminal processes of a series of processes of indefinite extent; and the intercalation of the intermediate processes between the known terminals can be accomplished only as the result of a psychophysical analysis.

It is the purpose of this monograph to indicate the lines along which an analysis of this kind may proceed. In Part I will be considered the subject's judgment of pain as a basis for the determination of the nature of the pain state as a mental content. In Part II will be discussed the second of the two terminal processes already mentioned, — the stimulation of pain. Part III will deal chiefly with the physiological interpretation of the results of psychophysical experimentation.

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# THE SENSATION OF PAIN

## PART I

### ANALYSIS OF THE PAIN JUDGMENT AS A BASIS FOR THE DETERMINATION OF THE NATURE OF THE PAIN STATE AS A MENTAL CONTENT

#### CHAPTER I

##### THE GENERAL JUDGMENT

IF a stimulus capable of producing pain is applied at one time to a subject who knows the purpose and methods of the experiment, and at another time to one who is entirely ignorant of the nature of the stimulus, there will be manifest differences in the resultant judgments or bodily reactions, and these will be clearly traceable to the varied conditions under which the experiments were made. An analysis of the various conditions of experimentation thus appears to be necessary before a satisfactory interpretation of the subject's judgment can be reached.

The various methods used in the experiments to be considered in this monograph fall into three fairly distinct classes of judgments. These I shall term "forced judgments," "general judgments," and "mixed judgments."

The *modus operandi* of the earlier experiments led naturally to the kind of judgment which I have called "forced," inasmuch as the subject was given but two choices, being required to say whether the sensation was "touch" or "pain." No description or qualification was required or allowed. This, it will be noted, is the method commonly used in psychophysical investigations,

notably in the determination of the initial threshold of sensation and the threshold of difference. For example, in the determination of the pain threshold, the subject's choice is limited to "pain" and "not-pain." The method is valuable here because the expectant attention of the subject is fixed upon a single quality of the sensation-complex, and thus the appearance of this quality (pain) is noted with greater exactness.

There are, however, in these judgments implications of mental processes other than the pain state, which render the interpretation of the results often uncertain. The most important of these is the alteration of sensation by *preperception*. There is no fact in psychology more clearly established than that of the influence which a preperceptual image has upon an incoming sensation. Illustrations of this fact abound: reaction time, for instance, is shortened if the subject knows in advance the nature of the stimulus to which he is to react; all threshold values are lowered by preperception; the least observable difference between two stimuli which were originally alike in quality or intensity is greater than that between two stimuli the difference between which was originally supraliminal. These are but a few instances of preperceptual influence. If now, in the judgments we are considering, the subject is required to subsume all experiences under touch or pain, he will have in mind a preperception, now of the one, now of the other, as a standard of comparison to which to refer the incoming sensation; if the preperceptual image, at a given instant, is that of pain, there will be a tendency to describe the incoming sensation as "painful." Moreover the preperceptual image itself does not remain constant throughout a series of experiments; subjects frequently speak of the fact that their concept or ideal of what pain is has undergone gradual, or sometimes sudden, changes during the course of the tests.

The method which leads to what I have called "general" judgments is not open to the same degree to these objections. To the subject there is given a variety of unknown stimuli, capable of producing various forms of dermal sensation; he

does not know whether the coming stimulus is hot or cold, wet or dry, moving or stationary, intense or weak. "Tell me what you feel" is the only direction given by the experimenter. Consequently there is no fixed preperceptual image vividly present in the mind. Even if the subject, in the course of experimentation, comes to form images of possible future sensations, these are so varied and numerous that they do not attain the intensifying force of the pain image or touch image in the simple forced judgment. The general judgment results from what may be called the "natural" or "analytic" method of psychological investigation. The subject starts with the concrete sensation-complex, the total result of a given stimulus, and enumerates such parts as stand out with some distinctness. He says, for instance: *I feel sharp, quick pain followed by a persistent after-image, here. It feels as though a hot needle had pierced the skin.* There is thus an opportunity for the study of pain in connection with the other dermal sensations with which it is always associated, and without the disturbing influence of an artificial direction of preperceptual attention.

Mixed judgments are obtained when the subject is required to give the judgment "touch" or "pain," but is asked to add a brief description of the sensation. He says, for instance: *I feel pain. It is lancinating. There is an after-image.* This form of judgment is of great value in the enumeration of the so-called varieties of pain.

It should be borne in mind, however, that the distinction between the forced and the general judgment is not an absolute one: in the last analysis, all judgments are forced; that is, they are all subject to certain predeterminations. For instance, the number of judgments possible in any given case is practically determined by the subject's preëxisting sensation genera, — his mental "labels," as Professor James would call them. To be able to say, "This pain is piercing," the subject must already have differentiated the class "piercing" from other sensational experiences. The existence and character of the subject's apperception-mass is thus an important factor in the production

of the judgment. Preperception, therefore, in some form, is present in every judgment; it cannot be eliminated by any method whatsoever; indeed it is a common experience that untrained subjects are of little value to the experimenter until he has in a measure guided their judgments by his own questions, since until he does this their reports are exceedingly meager. While it is true that every perception involves inferential elements, it is possible, for practical purposes, to distinguish between the relatively immediate experience and its escort of more remote influences. The experimenter, therefore, aims not to eliminate preperceptual conditions but merely to ascertain what they are and the degree of their influence.

The subject's terminology, also, demands some attention from the experimenter. If the subject says that a pain appears more "subjective" to him than does a color or a tone, does he mean that the pain gives him less knowledge of the stimulus than does the color or the tone, or that the pain is identified more closely than these with his own body, or that the pain does not appear to him to have any physical basis? There are many terms the connotation of which is so variable and uncertain that they should not be accepted without an attempt at closer definition.

The experimenter's pain judgment should be subjected to the same critical analysis that is necessary in the case of the subject's judgments. So-called immediate or introspective knowledge of pain may often contain concealed inferences which will impose upon even the analytic powers of the most skilled observer; and judgments may be all the more definitely predetermined by the experimenter because of his own ignorance of the existence of these inferences in the introspectively given data. The experimenter may in consequence direct or inhibit the subject's judgment, or force it to be accommodated to his own preconceptions. This will be manifested in the collation of the experimental data and in the formulation and derivation of conclusions.

When subjects are allowed freely to choose their own descriptions of the "pain datum," great individual differences are

manifest, even between subjects whose vocabulary is presumably of like extent. Some subjects confine their descriptive terms within a very narrow range, using only the most familiar words, while others are ready to use comparatively rare terms and occasionally to coin words. In the experiments to be discussed, the individuality of one of the subjects is shown in a marked degree in the number of words newly coined or used in an unusual sense. Other things being equal, the best subject is of course he who has a large vocabulary and a fine sense for the distinctions in words.

Other predeterminants of the subject's judgment might be mentioned: the natural reticence of some subjects, which shows itself in the conventional character of the judgments given; predispositions to hallucinations and illusions, which result sometimes in very graphic descriptions of pain; the tendency of sensations to grow as they are dwelt upon; and especially the great diversity in subjects in respect to their predominant type of imagination. The states resultant upon a given stimulation are expressed in very different terms by the strong visualizer and by the thinker of the audile or motile type. In one of the experiments discussed in this paper a painful stimulation led one subject, a strong visualizer, to give the judgment "a hot sensation from a pencil point that moved  $1\frac{1}{2}$  inches," while a subject not a good visualizer responded to the same stimulation with the judgment "a clutching feeling that goes down into the fingers." It is manifestly an error to call one of these judgments right and the other wrong, in so far as they are considered as reports of sensation and not as guesses concerning the nature of the stimulus.

Another factor that must be taken into account in a comparative analysis of judgments is the subject's theory of pain. If, for instance, he habitually thinks of pain as an intense degree of sensation, it is probable that his judgments of the quality of sensation are unconsciously influenced by his estimation of the quantity of the stimulus, and that he withholds the judgment "pain" until he has reason to believe the stimulus has attained a certain degree of intensity.

Enough has been said to show that there is no such thing as an absolutely free, unbiased judgment. The subject is free to range within the limits of his psychophysical tether, but beyond this he cannot go. He may take cognizance of things beyond these limits, but his *judgments* will be confined within the narrower circle. Psychology has long recognized the importance of these limitations as a factor in ideation and in the larger masses of thought; but it should not be forgotten that these are likewise involved in judgments of simpler experiences, *viz.*, the sensations. The number and character of our sensation categories is determined by experience. The blind man has no color categories. A psychophysical process stands back of every judgment, of the pain judgment no less than of the color judgment. A pain judgment is not to be viewed as a simple report of the immediate experience; it involves a knowledge of stimuli likely to act upon the organism and of the subject's previous reactions to those stimuli.

The highly complex character of the pain judgment and the extent to which it is predetermined by psychophysical conditions may be seen in the results of a series of experiments, made in the year 1899, in which the painful stimulations were interspersed between stimuli of varied character, the subject being ignorant of the character of the stimuli. No instructions were given by the experimenter to the subject in regard to the form or character of the judgment beyond the direction "Tell me what you feel." The subject's eyes were closed, and the hand stimulated was further shut off from the subject's view by a black screen. The subjects, who will be referred to as A, B, C, D, and E, were with one exception graduate students. The experiments were varied from time to time, as the object of the experiment was a comparison of the pain state with other states, in all cases the character of the stimulus being unknown to the subject.

The chief stimuli used in these experiments were needles, metallic disks of various diameters, the points of the æsthesiometer (dull and sharp), card edges (continuous and notched),

wooden surfaces of varying shapes and dimensions, the pipette, etc. Many of these stimuli were applied under varying conditions, — wet, dry ; hot, cold, indifferent ; moving, stationary ; constant, intermittent ; and, in the case of temperature stimuli, with or without contact with the skin. By means of these combinations and variations about one hundred different stimuli were made use of.

In the Appendix, pp. 69 f., will be found a tabulation of the results of this series of experiments. Although in the experiments the painful stimuli were interspersed among non-painful stimuli, I tabulate separately, under Schedule A, the judgments of A, B, and C in response only to those painful stimuli which were clearly supraliminal. Judgments of supraliminal stimulations are free from certain complications attendant upon threshold stimulation.

On examination these results furnish numerous illustrations of the various predeterminants of the general judgment that have been already mentioned. For example, C is a subject who is familiar with psychological terms ; B has done no work in psychology. The judgments of C contain many technical words and phrases which are lacking in those of B : "heat pain," "sensation," "körniges Gefühl," "diffused," "circumscribed pain area," "stimulus," etc. C's use of the term "körniges Gefühl" is a good example, also, of the determination of a judgment by the preëxisting sensation categories. If C had not been possessed of Goldscheider's term, it is doubtful whether the given experience would have been so exactly differentiated from others. Again, C's theory of pain probably influences the form of certain of the judgments : "heat pain, though no heat about it," "intense heat pain, but no sensation of heat itself," etc.

A and C show very clearly in their respective judgments the difference between the visual and the non-visual type of imagination. A's judgments are expressed in visual terms. She has always, she says, a visual image of the stimulus, and she finds it impossible to attend to the sensation itself until she has made this image reasonably distinct. She has, too, a visual image of

the point touched and of the surrounding region. In this series of experiments she felt herself a sort of spectator, viewing mentally the coming stimulus and the area stimulated. She reports that even in her abstract thinking she visualizes the relations of concepts by means of circles. C is not a good visualizer at any time.

The most important fact, however, brought out in these judgments is that the introspectively given pain datum is always accompanied by a reference to physical or physiological processes. In A's eighteen judgments the stimulus is *named* eight times, and *described* six times; no description of the stimulus is given in four judgments, although in two the area stimulated is described and in two its locality is mentioned. B's judgments involve in every case a reference, more or less remote, to the stimulus. C, on the other hand, in nineteen judgments names the stimulus but two times, otherwise refers to it once, describes the area stimulated once, localizes the stimulation but does not describe the stimulus three times, and gives the judgment in what may be called "sensational" terms twelve times. But even in these twelve judgments, which appear at first sight to contain no physical nor physiological reference, a closer analysis reveals in every case a remote reference to some characteristic of the stimulus or of the area stimulated. I shall not enter into this analysis at this point, as it can better be discussed in connection with the subject of varieties of pain. That C's references to the stimulus are more remote than are those of the other subjects is perhaps accounted for by the fact that this subject, because of previous training in psychological experimentation, is better able to attend to the relatively *immediate* experience, and to abstract from all except the more remote inferences.

So far, then, as the general characteristics of pain judgments are concerned, there is nothing to indicate that pain is felt by the subject to be other than a psychophysical fact. That is to say, there is no evidence in the judgments that pain is recognized as a mental state or "attitude" without reference to a nexus of physical or physiological processes.

Experimental introspection yields on close analysis a psychophysical datum to which the subject applies the term "pain," sometimes without, but usually with, a direct reference to the implicated physical and physiological processes. If we consider the pain state as an element in the total psychophysical datum, it is an element of abstraction, a *terminus ad quem* of psychophysical analysis; it does not appear in consciousness as an isolated element of mental experience. The setting of the *pain state* as thus given through introspection appears not to differ from that of touch. Pain is referred to associated physiological and physical processes as invariably as is touch or color or tone. Pain is looked upon by the subject as a "psychosis of limitation," to use Mr. Marshall's term, and not as one of "those general qualities of which intensity is an example." [102.]<sup>1</sup> The subject often says, "I feel pain from a needle, *here*," but never, "I feel intensity from a needle."<sup>2</sup>

The outcome of the analysis of "general" judgments of pain is, therefore, the conclusion that pain is a psychophysical fact, a psychosis connected with definite bodily states and physical antecedents in the same sense as are other mental states which are subsumed under the category of the sensations.

<sup>1</sup> These numbers refer to the Bibliography, pp. 79 f.

<sup>2</sup> That the pain judgment is the only basis for the determination of the pain state itself is admitted by Mr. Marshall, who is cited in this monograph as the most representative modern adherent of the views of the traditional psychology with respect to the nature and classification of pain. Mr. Marshall repeatedly insists upon the importance of introspective, as over against physiological, evidence in the formulation of a theory of pain and regards the *qualia* theory as the only view in which due regard is paid to introspective data.

## CHAPTER II

### QUALITATIVE DISTINCTNESS AND DISCRETENESS

Is there any one experience to which we refer when we use the term "pain"? In other words, does pain stand out as a clearly recognizable mental content, so that, no matter what its concomitants may be, the subject may speak of the presence of pain with the same definiteness with which he speaks of the presence of red or bitter?

The chief considerations that have led many psychologists to doubt the distinctness or uniqueness of pain are (1) the difficulty of isolating introspectively and distinguishing a weak pain from a strong sense perception, and (2) the variations in the pain quality itself.

Experimental results, however, show that the difficulty of distinguishing weak pains from intense pressures, etc., is not so great as it is commonly supposed to be. It is probably no more difficult to determine just when a pain appears than it is to determine just when a sensation from a minimal olfactory or auditory stimulus is felt. Weak stimuli in all sense departments are easily confused with other impressions; a "threshold stimulus" is, by definition, a stimulus that is just as often not perceived as perceived. That pain is sometimes hard to distinguish from intense pressure is, then, entirely in accordance with the laws of sensation. Nevertheless, in Griffing's algometric tests the subjects find it "easy to tell when the pressure begins to be uncomfortable, and the imagination does not seem to be a disturbing factor. Indeed the pain seems often to come with greater suddenness." [66.]

The judgments of untrained observers give evidence that the subject recognizes pain (in excess pains, at least) to be just as distinct and unique a fact of consciousness as touch, and

that he seldom shows any hesitation as to the application of the term "pain."

The seemingly endless *variety* observable in pains may appear to be inconsistent with the distinctness of the pain state. Pains are spoken of as aching, massive, sharp, acute, deep, lancinating, piercing, throbbing, etc. Ancient physicians recognized these and others as distinct qualities and grouped them in four classes: drawing, aching, throbbing, piercing. Mantegazza, whose classification of pains is one of the most exhaustive in recent times, enumerates nearly a hundred varieties of pain. [6.]

The results of certain experiments that form part of a series made in the year 1897-98 bear on the question of the varieties of pain. The methods used were such as to lead to judgments of the "mixed" or "partly forced" type; the subject was asked to say whether pain or touch was felt, and to add a description of the experience.

The procedure was a preliminary modification of that described in Part II, pp. 33 f. It will suffice in the present connection to know that the stimulus was the point of a needle carried by an arm projecting from a revolving wheel. The mass of the wheel and needle with its attachment was constant. The arm bearing the needle was lifted the desired number of degrees of the arc of the circle above the horizontal position and allowed to drop freely upon a selected point of the hand of the subject, which was held firmly in a plaster cast and hidden from view by a screen. The intensity of the stimulus varied with the velocity of impact, which was proportional to the amount of displacement of the arm from the horizontal and was measured in degrees as indicated by a graduated scale. The experimenter manipulated the apparatus and recorded the subject's judgment; an assistant watched the impact of the needle upon the skin, using a magnifying glass to determine the location of the points stimulated.

The judgments which I shall subject to analysis are the results of 374 experiments upon six points on the ball of the left thumb of two subjects, B and D. In 241 experiments

the stimulus was of an intensity which ranged, as measured in terms of the angular displacement of the arm and needle, from  $25^{\circ}$  to  $50^{\circ}$ . The judgments showed this to be the range of the threshold stimulus of pain. In 133 experiments the stimulus ranged from  $58^{\circ}$  to  $65^{\circ}$  and was decidedly above the pain threshold. As the differential sensitivity of the six points and the two subjects does not enter into the present question, the results from all points are collated together and classified according as the judgment is "touch only," "touch and pain," or "pain only." The collation of results which follows presents also the descriptive words used in the various judgments of the stimulus and the number of times each type of description occurred.

I. Liminal pain stimulus, ranging from  $25^{\circ}$  to  $50^{\circ}$ .

1. Judgment — "touch only."

*Description*: — sharp, 39; pricking, 23; dull, 18; blunt, 14; tingling, 10; delicate, 9; cold, 4; scratching, 3; fine pointed, 3; light, 2; sticking, 2; gentle, 1; followed by feeling of "flesh rising," 1; compared with preceding sensation (not so sharp, duller, etc.), 17; no description, 21. Total, 167.

2. Judgment — "touch and pain."

*Description*: — sharp touch passing into pain, 36; piercing touch passing into pain, 6; touch with pain, 5; touch into pain, 4; touch into pricking pain (one described as being like a rose thorn), 4; dull touch with pain, 1; touch into dull pain, 1; slight pain with touch, 1; dull touch into pain, 1; touch (as if the needle had caught) passing into pain, 1; compared with the preceding sensation, 3. Total, 63.

3. Judgment — "pain only."

*Description*: — pricking, 6; sticky, 1; no description, 4. Total, 11.

II. Supraliminal pain stimulus, ranging from  $58^{\circ}$  to  $65^{\circ}$ .

1. Judgment — "touch only."

*Description*: — sharp, 4; dull, 4; pricking, 3; blunt, 1; tingling, 1; sticking, 1; compared with preceding sensation, 1; no description, 2. Total, 17.

2. Judgment — "touch and pain."

*Description*: — pain with touch, 6; touch with slight pain, 1. Total, 7.

## 3. Judgment — "pain only."

*Description*: — pricking, 30; sticking, 22; stabbing, 14; sharp, 8; tingling, 3; acute, 3; cutting, 3; slight, 2; blunt, 1; dull, 1; lingering, 1; jabbing, 1; scratching, 1; compared with preceding sensation, 13; no description, 6. Total, 109.

The following schedule combines all these judgments under the two heads of Touch and Pain, and adds the descriptive terms employed arranged in order of frequency:

Touch, *descriptive terms*: — sharp, 79; pricking, 27; dull, 24; blunt, 15; tingling, 11; delicate, 9; piercing, 9; cold, 4; scratching, 3; sticking, 3; fine pointed, 3; light, 2; "flesh rising," 1; "as if the needle had caught," 1; gentle, 1; compared with the preceding sensation, 21; no description, 41. Total, 254.

Pain, *descriptive terms*: — pricking, 40; sticking, 23; stabbing, 14; sharp, 8; slight, 4; tingling, 3; acute, 3; cutting, 3; dull, 2; blunt, 1; lingering, 1; jabbing, 1; scratching, 1; compared with the preceding sensation, 16; no description, 70. Total, 190.

Many of these descriptive terms do not refer to the sensation at all but to the size, shape, or other characteristics of the objects supposed by the subject to have been used as stimuli. Many of the so-called varieties of pain are therefore merely inferences concerning the character and mode of application of the stimulus. These terms may be classified in the following manner:

*Qualitative descriptions*: — Touch: tingling, delicate, pricking, sticking, "flesh rising," piercing. Pain: aching, cutting, biting, paralyzing, sore, stabbing, clutching, sticking, stunning, pricking, tingling.

*References to the stimulus*: — Touch: sharp, dull, blunt, fine pointed. Pain: blunt, dull, sharp.

*References to the rapidity or intensity of stimulation*: — Touch: light, slight, heavy, hard, light blow, heavy blow, gentle. Pain: slow, intense, violent, very intense, hard, lingering, slight, acute.

*Application and diffusion of the stimulation*: — Touch: scratching, "as if the needle had caught." Pain: scratching, "spreads slowly," superficial, deep.

*Temperature*: — Touch: cold.

I have used the term "qualitative descriptions" for adjectives not otherwise classified. Such a grouping is, however, artificial;

and a little reflection will show that the "qualitative descriptions" may be subsumed under one of the other heads. For instance, the judgments "biting," "cutting," and "clutching" may fairly be regarded as references to the nature of the stimulus but little more remote than the reference in "dull," "blunt," etc. A pain is denominated "aching" because of its extent and its dead level of intensity. A "tingling" pain is one that is oscillatory, the particular vibrations being of comparatively slight intensity. All of the terms used for the so-called "varieties" of pain described in the foregoing experiments may thus be regarded as references to local or temporal characteristics of the stimulation.

Other seeming variations in the quality of pain are clearly due to the intermixture of other sensations. A heat pain, for instance, is a complex sensation made up of heat and pain. Occasionally subjects skilled in introspection are able to distinguish between the pain and the temperature sensation of a burn. The subject C, for instance, in the experiments in the last chapter judges five times "heat pain, but no sensation of temperature," and eleven times in a total of fifteen stimulations with heated objects "pain without temperature." In one instance the judgment is "a sharp painful prick. It is hot, but the heat is not painful; it is only the prick that is painful." Such an immediate introspective analysis of the sensation-complex into its components is, however, comparatively rare; for most subjects the elements have so completely fused in consciousness that their separation is impossible, so far as any one experience is concerned. In this respect, however, pain does not differ from other sensations; a sensation of blue, pure and simple, is an abstraction just as a sensation of pain is.

The pain state, then, appears to be simple and invariable, and the so-called varieties of pain are evidently complex sensational experiences which resemble one another in the presence of the common element, pain. The *pain* from a heat stimulus does not differ from that produced by a pressure stimulus, though the *total experience* differs widely in the two cases. The term

"pain" refers to an experience as distinct and definite as that of "blue." There is every evidence that, in the case of supraliminal stimulation at least, "pain is presented in consciousness with the distinctness, difference, vividness, and isolation that characterize simple sensations." [168.]

The failure of many psychologists to recognize amid the diversity of sensation-complexes containing the pain datum the simple, distinct, and unique character of pain itself has been due in large measure to a confusion of pain with the *disagreeable*. Even Mr. Marshall, who recognizes the unvarying character of pain in all cases (as a "primary *qualé*" of sensations), includes among "painful sensations" a large number of states which might better be classed as uncomfortable or intolerable.

That a confusion of pain with the disagreeable should occur is not surprising. Painful things *are* disagreeable usually; hence the identification of the two. Professor James, in his treatment of "discrimination," gives some excellent illustrations of the fact that a total impression is unanalyzable if its elements have never been experienced apart from one another. "If all cold things were wet, and all wet things cold; if all hard things pricked our skin, and no other things did so, is it likely that we should discriminate between coldness and wetness, and hardness and pungency, respectively?" [80.] It is in some such way that the popular identification of the painful and the disagreeable has come about. In ordinary experience pain is always highly disagreeable, and the intensity of the *Unlustgefühl* increases with the intensity of the *Schmerz*; yet the converse does not hold good: the disagreeable is not always painful. Hence pain has come to be regarded as including only the highest intensity of the disagreeable.

It is because of this mistaken extension of the term "pain" that Mr. Marshall finds so large a number of "differentials" for pain, and speaks not only of "cutting pains," "pricking pains," etc., but of "intellectual pains" as well. As to "intellectual pains," which Mr. Marshall says "are known to all thoughtful people," it is hard to see that we "have here phenomena very

different from anything noticeable with the recognized sensations." [103.] A so-called intellectual pain is nothing more than the feeling of the disagreeable which results from bodily reactions to cerebral occurrences. It is true that "we never have a *cold* thought . . . or a *sonorous* emotion," as Mr. Marshall says, but it is equally true that we never have a painful *thought*, strictly speaking, — which merely amounts to saying that pain involves physiological as well as psychical processes.

The isolation, or *discreteness*, of pain is sometimes thought to present a problem differing from that of its *distinctness*; and some psychologists who find pain to be a clearly recognizable phenomenon regard it as a mere modification of touch, heat, or other sensations and incapable of being experienced apart from these.

Neither pain nor any other sensation is "discrete" if by this term it is meant that a "sensation" can be experienced apart from all other mental content. A pain pure and simple is as impossible as an absolutely isolated red. Pain has, however, the only kind of discreteness which can be predicated of any sensation,—discreteness as an entity of abstraction.

The most important evidence for the discreteness of pain is to be found in the investigations that have been made of analgesic, anæsthetic, and related conditions, in which it is seen that certain forms of sensibility may be destroyed, diminished, or increased, while others remain unchanged.

Analgesia and partial anæsthesia may be produced by the action of certain drugs. Donaldson finds that the application of cocaine to the conjunctiva destroys the sense of pain but does not impair that of temperature. Shore finds from experiments on the tongue with gymnema that touch and temperature may remain when other forms of sensibility are lost. Some important investigations have recently been made by Kiesow in which it has been found that touch, pain, heat, and the sensations of taste are not equally diminished by the application of cocaine to the tongue and mouth. Pain from a heat stimulus, for instance, persists on the tip of the tongue after the taste sensation has disappeared. On some parts of the tongue, with

a ten per cent solution of cocaine, pain disappears, although touch remains and can be excited by a ten per cent solution of salt (which here gives no taste sensation). [84.]

Goldscheider's investigations of the action of cocaine show that the *intensity* of the effects of the drug differs for various sensations. The tickle sensation is most affected, next temperature, then taste, and finally pressure, sense of locality, and pain. On the tongue a ten per cent solution of cocaine will cause the sensation of temperature to disappear entirely, while sensations of pain from a mechanical stimulus can still be felt, though much weakened. Contact, though weakened, can still be felt after cold and heat sensations have disappeared. In one experiment, before which the skin was blistered and the epidermis removed, it was found that after the application of cocaine "contact with a cylinder only slightly heated gave a painful sensation without a trace of heat-sensation. . . . Mechanical stimulation does not produce this painful sensation." Carbolic acid applied to the tongue in five per cent solution destroys the sense of taste and of temperature, but only weakens pressure and pain. Chloroform and also the drug kava-kava have a similar effect. All of these drugs produce a hyperalgesia toward heat stimuli, whereas menthol produces a hyperæsthesia for cold stimuli. [52, 59.]

Ribot shows that saponin will destroy the sense of touch, while that of pain remains unimpaired. [132.] Richet finds that in abnormal states produced by the use of arsenic and belladonna, the sense of temperature remains, although the skin is anæsthetic to other forms of stimulation. [137.]

These experimental results are confirmed by pathological evidence. Puchelt reports four cases of patients who showed thermanæsthesia, although the touch and the pain sense were unimpaired. Berger, Mosler, and Landois give similar instances, among others a case of hyperæsthesia toward temperature stimuli with impaired sense of pressure and locality. Fritz reports a case of typhus in which analgesia was found. [Cited by Goldscheider, 43.]

"Gowers has reported a case in which . . . there was complete loss of pain on one side without loss of touch." [Cited by Witmer, 169.] Mosler has recorded a case the opposite of this: "A woman with brain disease was insensitive to touch on the right side, though pain and temperature sensations remained normal. . . . In a case of locomotor ataxia, also recorded by Mosler, the prick of a pin caused pain everywhere, yet on the left leg the pressure sense was so dulled that the patient could not distinguish between 100 and 500 grams, nor even feel their weight on the skin." [Cited by Strong, 150.] Herzen records a case of myelitis in which the sensibility to cold and touch disappeared entirely in the lower extremities, while pain and heat were retained. [Cited by Dessoir, 23.]

Adamkiewicz mentions as an illustration of elective anæsthesia the fact that while the sensitivity to touch and pain is increased on the skin area to which a blister has been applied, and is diminished on the opposite side on the corresponding spot, this "sinapismic transfer" does *not* take place in the case of temperature sensations. [Cited by Dessoir, 21.]

Richet found that contact cannot be made hyperæsthetic. If a light touch is not perceived in a normal state, it will be perceived in a hyperæsthetic state not as touch, but as pain. Dessoir says he has never found a case of hyperæsthesia for temperature, even in spinal meningitis. Brown-Séquard notes the fact that hyperæsthesia does not give increased accuracy in localization; the patient often tends to multiply the number of sensations, — to feel three instead of two touches, etc. [Cited by Wundt, 177.]

In the hypnotic state a common phenomenon is the suspension of one form of sensibility while others remain unimpaired. Demarquay had a subject who in the hypnotic state was analgesic, although his sense of touch was intact. Janet's patient, Leonie, could be made to lose tactile sensibility within a circular area on the arm. [81.]

There are a few cases on record of natural analgesia. S. Weir Mitchell cites a case reported by a Georgia physician, Dr. Eves.

The general health of the patient was good, yet he entirely lacked the pain sense, undergoing two serious surgical operations without experiencing any pain. [109.] Witmer reports the case of a man for some time under his observation, who could at will make himself insensible to pain from pricking, cutting, burning, and electrical stimuli. [170.]

The *delay* observable in the pain sensation is closely connected with the phenomena of analgesia and selective anæsthesia. If the hand is brought into contact with a hot object, the contact is felt before the pain; if the algometer is pressed quickly on the skin, the pressure sensation again precedes the pain. The cold of a knife is felt before the pain of a cut. Wounds are commonly not felt to be painful for some time after they are received. [Richet, 138.]

The explanation of these facts which is given by Lehmann is unnecessarily complicated. Lehmann explains the delay of pain in burns as due to the fact that the reaction time for heat is greater than that for pressure; consequently heat pain is felt *after* painless pressure. The seemingly delayed pain in the case of a needle prick is the pain of a secondary sensation. [89.] Marshall suggests that in this latter case "a second set of nerves, *viz.*, those producing the sense differentiation known as pricking or cutting, are brought into action after those of touch..." [104.] Analgesia he explains on the same hypothesis: that "the capacity to experience one form of sensation (*e.g.*, cutting, pricking) in a certain part of the body may be cut off, together with the capacity for pain-giving which goes with it, without cutting off in the same parts the capacity to experience other sensations (*e.g.*, those of pressure, heat, cold) with their capacity for pain-giving." [105.] It is difficult to see how this hypothesis of a cutting-pricking-laceration sense would, even if demonstrated, serve to explain more than a few of the varieties of analgesia and anæsthesia. It certainly furnishes no satisfactory explanation of such a case, for instance, as that already cited from Goldscheider's experiments with cocaine, in which the pain from a heat stimulus was clearly felt although there

was no trace of temperature, and the painful sensation could not be excited by mechanical stimulation. Furthermore the hypothesis is superfluous; it is simpler and more satisfactory to regard pain as a sensation than to posit an additional sense (cutting, pricking) in order to account for a limited number of the phenomena of pain.

## CHAPTER III

### THE PAIN JUDGMENT AND JUDGMENTS OF OTHER SENSATIONS

IN the traditional treatment of pain, frequent reference is made to certain characteristics which are believed to differentiate pain from true sensations. One of these is lack of localization. A pain, it is said, is seldom localized with the same definiteness and accuracy as a tactile sensation, and many pains are almost entirely devoid of local reference.

I give in Schedule B of the Appendix, p. 73, a tabulation of general judgments of unknown stimuli in which the pain datum does not appear. The general judgments of supraliminal stimuli, recorded under Schedule A of the Appendix and discussed in Chap. I, pp. 6-9, were obtained in the same series with the judgments of non-painful stimuli. The two records furnish, therefore, a fair basis for the comparison of pain judgments with judgments of other sensations. As it is impossible to publish, even in an appendix, the full records of this series, I have recorded, in cases where the stimulus was applied many times, the most frequent judgment of the subject. In a few cases, where the stimulus was applied only four or five times and the resultant judgments were all different, I have arbitrarily recorded the *first* of the judgments given.

On examination, Schedule B exhibits the tendency of the subjects to certain frequently repeated and, in some cases, constant errors in the localization of the stimulus or in the estimation of its shape and size. In the stimulation with the two points of the æsthesiometer, for instance, A frequently judges the two stimuli to be unlike: one is often sharp and the other blunt; or, more frequently, one is a point, the other a large, vaguely defined surface. In the contacts with heated, unheated,

and cooled circular and rectangular surfaces, the circumference is seldom distinct, the subject using frequently the expression "diffuse, vague outline."

In twenty experiments with a "continuous card edge," twenty and thirty millimeters in length respectively, A almost without exception judged the card edge either to be a "circle," or "circular surface," or "two vague contacts"; B judged the same stimulus to be "a blunt and a sharp point," or "two blunt points and connecting line like a dumb-bell projected on a flat surface, each end of the size of a finger tip." In twenty experiments with each subject, with cards having three and five points, at no time does either subject mention the correct number of points. In twenty experiments with rectangular wooden surfaces, neither subject gives a correct judgment of the form of the stimulus.

Results such as these show that tactile and thermal sensations are seldom localized with any great degree of accuracy, and that the form and size of the stimuli are not usually judged correctly. Pain is localized with as much accuracy as are the sensations of touch and of temperature.

There are no pains that are entirely unlocalized with reference to the body. Pains of the internal organs have been described by some psychologists as devoid of local character on the ground that these organs are devoid of tactile sensation, and consequently lacking in the locality feeling. Aside from the error involved in the ascription of the locality feeling only to the group of sensations known as tactile (an error which will be discussed later), the fact itself may be called in question.

It is not inconsistent with the localizability of pain that its "extensity" is of a more shifting and variable character than is the extensity of tactile sensations. This instability of pain extensity is the phenomenon usually referred to as the irradiation or diffusion of pain. It is especially noticeable in the pains mediated by the sympathetic nervous system. Richet calls attention to the fact that as a pain increases in intensity it

increases in extensity. When he applied an electric stimulus to a single point on the skin by means of the rheophore, he found that the point was always surrounded by a "painful circle" whose area increased with the area of the stimulation. Dr. S. Weir Mitchell reports three cases of patients suffering from nervous diseases, in all of which an increase in the intensity of the pain was followed by increased irradiation. A patient of Valleix had, as the result of a contusion of the trigeminus, an occipital neuralgia; then pain in the cervico-brachial region; then in the thoracic nerves. [135.] Such cases are seen to present no exception to the localizability of pain if it is remembered that the bodily part affected is seldom coextensive with the original stimulus.

It should be remembered that the correct localization of a pain does not mean necessarily its localization at the point of stimulation. Sometimes pain is felt only at the point of stimulation; sometimes, as we have just seen, in a much larger area; sometimes at a point far removed from the place of stimulation; sometimes both at the point of stimulation and at a distant point. The pains from faradization of nerve trunks, "referred pains" and "sympathetic pains," belong to the last two of these classes. It is a curious fact that electric stimulation of a sensory nerve may give pain at the place of application and a heat or cold sensation in the periphery. [51.] The same phenomenon is observable in the case of mechanical stimulation of a nerve trunk.

Head, Mitchell, Dana, and others report numerous cases of "referred pains." Allocheiria, "a pain or other sensation which is referred to a symmetric part of the body," is sometimes found in *tabes dorsalis*. [Witmer, 171.] De Fromental has prepared a tabulated list of points of the body which are associated sympathetically. Gubler refers to these pains in associated regions by the significant name of *répercutées*. [Beaunis, 5.] Richet calls them "synæsthesias" and finds them in normal as well as abnormal cases. [135.] Among normal synæsthesias may be mentioned the pain felt in the teeth as the result of a

grating sound, and the pain in the temples from the contact of the tongue with ice.

These algesic synæsthesias, however, are entirely analogous to the auditory and visual synæsthesias frequently found. A pain is no more lacking in localizability because it is felt in a bodily part other than the part stimulated than is a musical sound because it excites in some persons a color sensation. (See two cases reported by Whipple [167].)

Those who think pain to be lacking in localizability explain all apparent references of pain to definite bodily parts as due to the local color of the tactile or other sensations with which, on this theory, pain is always conjoined; the local color of a needle prick, for example, belongs to the tactile sensation *per se* and not to its painful aspect.

Such a view ignores the fact that, strictly speaking, neither pain nor any other sensation possesses *per se* the attribute of localizability. If a pencil point be brought into contact with the skin, the result is a composite state of which the touch is only one relatively prominent part, — such a part, for instance, as is the fundamental tone in a clang. In addition to the touch quality the stimulus calls forth a regional sensation-complex which differs for various parts of the body. In the process of development, touch has become associated with kinæsthetic and somæsthetic elements, and these are present in the psychosis resulting upon stimulation of the skin. It is to the varying complex, and not to the simple touch quality, that localizability belongs; and the localizability of pain is therefore nowise explained by attributing it to the accompanying tactile or other sensations.

There underlies such theories as this a fundamental error to which reference has already been made, — the treatment of sensations as entities, — from the synthesis of which complex psychoses are formed. The fact is ignored that red and bitter have no existence other than as products of abstraction. To regard them as “psychical elements” is a convenient assumption in the classification of psychological phenomena.

Closely connected with the supposed non-localizability of pain is another characteristic which, on the traditional theory, differentiates pain from sensations. The literature of pain is full of references to its *subjectivity*. "Our special sensations," says Lehmann, "are projected by us into the external world and are regarded by us as qualities of *things*. Feeling [and in feeling he includes pain], on the contrary, is only in the subject." [90.] "Feeling," says Stricker, "is our perception of our bodily state; sensation our consciousness of something that we refer to the outside world." "Pain or pleasure," says Kant in the *Critique of Judgment*, "is that element in an idea which is purely subjective, and which is in no sense a cognition." "While the *Vorstellung*," says Lehmann, again, "always stands to us for some *thing*, feeling is connected only with the subject. . . . We do not regard pain as a quality of knife or fire." [91.]

This distinction between pain and the sensations rests upon the confounding of a sensation with its stimulus. No sensation, whether of color or of pain, is a "quality of external objects"; as the culmination of a psychophysical process it bears no resemblance necessarily to the initial stage of the process. The truth is that the distinction is one of degree rather than of kind. In the process culminating in a sensation of color the stimulus appears to play a relatively greater, and the sense organs a relatively less important, rôle; in that of pain the contribution of the stimulus is apparently less, and that of the sense organ greater. But sensations of heat and cold are only a little removed from pain so far as their intracorporeal character is concerned. As Strong suggests, if feelings of temperature were *always* due to the cause to which they are now occasionally due, — changes in the circulation of the blood or to the increased or diminished animal heat, — we should account heat no less subjective than we now account pain. [150.]

## PART II

### THE STIMULATION OF PAIN

THE facts which lie open to the immediate observation of the experimenter, and from which psychophysical analysis must proceed, have been shown to be the stimulation and the subject's reaction. The subject's reaction has been discussed in the preceding chapters; it is necessary now to consider certain questions connected with the stimulation of pain.

The relation of the pain psychosis to extracorporeal objects or qualities of objects presents a peculiar difficulty in the classification of pain. A color sensation stands in a specific relation to ethereal vibrations of an assignable frequency, and tones to air waves, but with what quality of objects, with what physical process can pain be said to be correlated? As Stanley expresses it, if pain were thus related to any mode of objects, "there would have been long since a department of physics which would have treated that basis just as it treats light, heat, sound, etc." [146.] Pain thus appears to differ from true sensations in that while these represent actual differentiations in our environment, pain does not represent any such differentiation, but is excitable by any stimulus of sufficient intensity, whether mechanical, chemical, thermal, or electric.

This "intensity theory" of pain, as it is commonly called, ignores the fact that the very useful and convenient distinction between the quality and the intensity of stimuli has no significance apart from *psychophysiological* considerations. External stimuli, if conceived of merely from the physicist's point of view as vibratory movements, differing only in the frequency, amplitude, and form of vibration, present no such distinction as that which is indicated by the terms "quality" and "intensity." To repre-

sent such a distinction as inherent in external processes *per se* is to load our physical concepts with psychophysiological data.<sup>1</sup>

This distinction between the quality and quantity of external stimuli *per se* grows out of that concept of the nature of a stimulus which underlies the traditional theory of pain. The stimulus is looked upon as a permanent "mode of objects" which is itself perceived by means of the sensation process: the ultimate ground of the differentiation of sense qualities is found in the external object.

This concept of the stimulus is in essential agreement with those primitive theories of Greek philosophy according to which the excitant of sensation is an *effluence* from the external object. When the fire from external bodies, says Empedocles, passes through the pores to the fire of the eye we have the sensation of white or brightness; when water passes in, of black or darkness; white, black, red, green correspond to the four elements; the skin itself is hard and so perceives hardness, etc. [149.] According to Alcmaeon, the taste sensation is excited by an actual absorption of the food, which has been softened and melted by the tongue; and sound is the result of an actual passing of the external air through the hollow ear. Even Anaxagoras, who makes the percipient to be *unlike* the perceived, holding, for instance, that "rough" is perceived by the "smooth" of the skin, yet looks upon the stimulus as an effluence from the external object. The Aristotelian doctrine, which represents the high-water mark of Greek psychology, offers a refinement upon these theories in the notion that the organ takes on the *form* of the external object without its matter, as wax takes on the impression of a seal without its metal. By this Aristotle indicates his view that the stimulus (the objective quality) becomes known to the soul by an intervening

<sup>1</sup> It is only by ignoring the purely relative character of quality and intensity that such a theory of sensation as Preyer's *Elemente der reinen Empfindungslehre* is developed, in which quality and intensity are treated as two different kinds of things, "conforming to the rules governing lytic and thetic operations." [129.] Herbart's treatment of quality and quantity involves a similar notion.

physiological *process*, and not by the direct transmission of an image or copy. Color, for instance, belongs to external objects and affects the soul by moving the medium (transparent air) which, in turn, moves the "potentially transparent" water in the eye and makes it "actually transparent." Aristotle, however, like his predecessors, looks upon the stimulus as a quality of the external object which is faithfully imaged in sensation. [149.]

Psychology has never been able to show the parallelism between sensations and their extracorporeal excitants which these "physical" theories of sensation would appear to demand. The vibration continuum of the physicist's external world presents no such sharply defined groups as those of tastes, smells, sounds, colors, pressures. That one part of the physical series has a vibration rate of four hundred billions, and another of a little less than four hundred billions, furnishes absolutely no explanation of the abruptness of the change from the sensation of red to that of heat; nor does an equally slight change in the movement process account for the leap from tickle to pressure or from pressure to pain. The temperature sense is a marked illustration of the impossibility of correlating the quality of certain sensations with extracorporeal stimuli. The physical series, which in this case may be represented by a single straight line, a continuous scale of vibration frequencies, is cleft in twain by the reacting organism, and each part of the series is correlated with a different quality of sensation. There is no differentiation in the physical stimulus that can account for the specificity of heat and cold, and it is only by abandoning the concept of the stimulus as exclusively extracorporeal that a theory of temperature is made possible.

The specific stimulus of pain must therefore be sought in intracorporeal processes. The first step toward the discovery of these processes is the examination of the distribution of pain on the periphery and in the internal organs of the body.

The methods which are chiefly relied upon in the investigation of the peripheral local discreteness of pain employ mechanical, thermal, and electric stimulation of the skin, point

by point. Of these the mechanical stimulus has proved itself the most satisfactory. Two varieties of punctiform mechanical stimuli were employed in a series of experiments carried on in the psychological laboratory of the University of Pennsylvania during the years 1897-98. These were (1) the pressure of a bristle, and (2) the impact of a needle point.

The experiments with the bristle were made in accordance with the method first employed with satisfactory results by von Frey. [36.] The area of the cross section of a number of selected bristles was measured by the micrometer. The strength of the stimulus was ascertained in terms of the greatest weight that could be lifted by the bristle without causing a deformation of the bristle. This was determined by placing the bristle vertically in one of the scale pans of a balance and then weighting the other scale pan until the bristle began to bend. The weight required to cause the bristle to bend, its *Kraft*, to adopt von Frey's term, represents the total resistance and greatest intensity of the stimulus, since the resistance decreases as soon as bending begins. The *Kraft* divided by the area of the cross section gives the *Druck*, the pressure per square millimeter. For instance, one of the bristles used in the experiments of 1897-98 had an area of .0283 mm.<sup>2</sup>, a *Kraft* of 2.89 g., and a *Druck* of 102.12 g./mm.<sup>2</sup>.

In a preliminary series of tests made in the early fall of 1897, only the *Kraft* of the stimuli was measured. This series included 1884 experiments made on three subjects. With the subject K, eight points were tested within a small area on the back of the right hand; with the subject I, five points on the palm of the right hand; with the subject J, five points on the palm of the right hand. The subject was asked to give the judgment "touch" or "pain." The only result deserving of mention in this preliminary series is that in the case of the subject K, where a test was made of the relative sensitivity of the furrows or depressions of the skin and the more elevated portions, the furrows seemed to be slightly more sensitive, — a fact noted by Goldscheider and others.

This preliminary series was followed by a series in which more accurate measurements of the stimuli were taken, the *Druck* as well as the *Kraft* being recorded. The *Kraft* of the nine stimuli used ranged from 2.40 g. to 20.88 g., and the *Druck* from 24.45 g./mm.<sup>2</sup> to 102.12 g./mm.<sup>2</sup>. A bristle stimulus of 20.88 g. *Kraft* and 97.09 g./mm.<sup>2</sup> *Druck* was found always to excite pain.

The points tested were, in the case of subject I, five points on the palm of the right hand, ulnar side; with subject J, five points on the palm of the right hand, above and between the third and fourth fingers; with K, five points on the back of the right hand. In all, 675 tests were made, 200 each with J and K and 275 with I. The utmost care was taken to prevent the possibility of error in the location, from day to day, of the points tested, an impression of the region being made on smoked paper and afterwards photographed. The tests were not allowed to continue after the subject showed fatigue.

The results of these experiments yielded no conclusive evidence either for or against the theory of the peripheral local discreteness of pain, and the records are therefore not embodied in this monograph. Slight differences in the sensitivity of the various points were observed at times, but these were not found to be constant throughout the series.

My experience with these tests has convinced me that the method is open to several objections which tend to invalidate any results that may be reached. Chief among these is the difficulty of applying a flexible stimulus *vertically* at all times; a slight deviation of the bristle stimulus from the perpendicular causes only a portion of its cross-sectional area to be applied to the point stimulated. This difficulty increases when the bristle has been used so frequently that it begins to be permanently bent. My subjects frequently said: "I feel as if only the *edge* of the bristle touched me." It is, moreover, hardly possible to prepare a series of stimulus bristles in which the *Druck* and the *Kraft* shall exhibit uniform gradations.

A further difficulty lies in the fact that the use of stimuli varying so greatly in their cross-sectional area as did those in

the experiments under discussion makes it of the utmost importance that the experimenter be certain of the unit of comparison in determining the pain threshold. As to whether this unit of comparison is the *Kraft* or the *Druck*, or a quantity logarithmically proportional to one or the other of these, experimenters are by no means agreed. Von Frey uses, as I have shown, the *Druck* of the stimulus hair, the force exerted upon each surface unit. "Two hairs," he says, "of 90 and 440 *Kraft* and 30 and 163 mm.<sup>2</sup> cross-section exert the same pressure, for the second hair, although five times as stiff, has five times as great a cross-section." In other words, von Frey makes the intensity of the stimulus to vary in inverse proportion with the area stimulated. In the *Untersuchungen* he reports a careful investigation of this subject by means of an apparatus in which could be inserted stimuli of 2, 3, or 4 mm. diameter. These stimuli were small brass rods. From a comparison of the results with this apparatus and those with the stimulus hairs, von Frey believes the pain threshold to be measurable in terms of the *Druck*; in other words, the pain threshold for 1 mm.<sup>2</sup> of the skin when stimulated by a hair of .2 mm.<sup>2</sup> cross section is the same as the pain threshold of the same 1 mm.<sup>2</sup> when the stimulus is a rod of 3 mm. diameter. [41.]

Nagel [115] calls in question the validity of using the *Druck* as the unit of comparison. He reports three series of experiments in which he used, successively, as stimuli: (1) two hairs of equal *Druck*, of which one has a *Kraft* as many times greater than the other as its cross section is greater; (2) two hairs of equal *Kraft*, but unequal cross section and unequal *Druck*; (3) two hairs of equal cross section, but unequal *Kraft*. In all these cases he found that the resultant sensation is determined, not by the *Druck* (the pressure on a unit of surface) but by the stiffness (*Kraft*) of the hair. This he explains as due to the fact that the cutaneous area stimulated is always greater than the cross section of the stimulus. "The skin acts as a cushion, which transmits pressure independently (to a certain extent) of the area directly stimulated."

My own results show that the stimuli, arranged in order according to the number of pain judgments which followed each, correspond more nearly to the order of *Kraft* than to that of *Druck*.

Griffing [67] has given some results that are interesting in connection with this subject. A region on the palm of the hand was stimulated by applying the circular bases of blocks of wood of various diameters. The relation of the areas to the pain threshold may be seen by the following averages:

Area . . . . .	.1 cm. <sup>2</sup>	.3 cm. <sup>2</sup>	.9 cm. <sup>2</sup>	2.7 cm. <sup>2</sup> .
Pain threshold . . .	1.4 kg.	2.8 kg.	4.4 kg.	6.6 kg.

According to these results, the pain threshold does not increase *proportionally* to the area, but "in approximately a logarithmic ratio."

I have cited these conflicting results to show that the question of the unit of comparison cannot be regarded as settled. Until this is settled indisputably, the interpretation of the results of any experiments in which the area of the stimulus is not fairly constant must be open to question.

The second method, which employed an inflexible stimulus, the needle, was found to be much more satisfactory in practice. The apparatus used in this series of experiments consisted of a free beam suspended on knife edges supported by a pedestal having a heavy solid basis to give stability and steadiness. To one arm of the beam was attached a jeweler's needle; the other arm carried a weight adjustable at different distances from the axis of oscillation. By means of this weight the arms could either be exactly balanced or the needle arm could be overweighted by any desired amount. In making an experiment the needle was raised above the horizontal line, the position of equilibrium when the two arms were exactly balanced, and allowed to fall upon the hand of the subject, which was placed to receive the stimulus where the beam in falling returned to the horizontal line, *i.e.*, the position of equilibrium. The distance through which the needle fell was measured in terms of the angular

displacement of the beam from the horizontal; the angular displacement was indicated by a pointer attached to the beam and moving over an arc of the circle graduated in fractional parts of a degree. In practice the moving mass of the needle arm was kept constant, the two arms being exactly balanced. The intensity of the stimulus varied, therefore, only with the velocity of impact, which was proportional to the distance through which the needle fell and was expressed in degrees of the arc of angular displacement.

The apparatus and the subject's hand were screened from his view. The experimenter manipulated the apparatus and recorded the subject's judgments. An assistant observed with the aid of a magnifying glass the point of the hand selected for stimulation and checked off the success or failure of each attempt to direct the impact of the needle to the desired point. The accidental stimulation of adjacent points was thus detected; in such cases the subject's judgment was disregarded in the collation of results.

The subjects were F and G, two graduate students. Ten points were selected for investigation, situated within an area of  $\frac{1}{2}$  inch square on the back of the left hand of each subject. The hand was kept fixed in position by resting the forearm and hand in a plaster mold specially prepared for each subject. The points selected on the hand were not marked in any way, as it was believed the use of a dye would affect the sensitivity. The experimenter located the points by reference to the furrows, pores, and other minute irregularities of the skin. A description of the topography of the area, with the points located and numbered, assured their identification at any time. A print of the area taken on smoked paper was of some assistance and was employed in some experiments of this series.

The method employed in determining the minimal threshold of the points to pain was a variation of the method of minimal gradation. The procedure was as follows: Each of the points was stimulated at  $1^{\circ}$ ; in a second set of experiments at  $2^{\circ}$ ; then at  $3^{\circ}$ ; then at  $4^{\circ}$ , etc., until the subject had reacted with a

pain judgment to the stimulation of every point. As soon as pain appeared with any one point, the stimulus giving pain was recorded in degrees, and the point was omitted from the next succeeding set of experiments. This entire procedure was repeated ten times with each point, and an average minimal threshold of pain found for each point. In the following table, the ten points are arbitrarily arranged for each subject in the descending order of sensitivity to the pain stimulus, in accordance with the results obtained by the method just described. The points are designated by the letters from *a* to *j* for subject F, and *k* to *t* for subject G.

	Points stimulated	SERIES I						SERIES II					
		PAIN			TOUCH			TOUCH			PAIN		
		Order	Threshold		Threshold		Order	Order	Threshold		Threshold		Order
			Av.	Av. Var.	Av.	Av. Var.			Av.	Av. Var.	Av.	Av. Var.	
<i>Subject F</i>	<i>a</i>	1	2.8	.32	.60	.32	3	3	.31	.08	6.50	.60	2
	<i>b</i>	2	2.8	.38	.75	.30	5	6	.60	.22	5.70	.56	1
	<i>c</i>	3	2.8	.36	.85	.21	7	7	1.05	.08	9.05	.76	10
	<i>d</i>	4	2.8	.32	1.50	.20	10	10	1.20	.16	7.85	.81	7
	<i>e</i>	5	2.9	.36	.30	.09	1	1	.25	.00	6.65	1.02	3
	<i>f</i>	6	2.9	.18	.75	.32	6	4	.50	.10	7.50	.70	5
	<i>g</i>	7	3.0	.50	.73	.45	4	5	.50	.10	6.95	1.16	4
	<i>h</i>	8	3.1	.48	1.18	.39	9	8	1.05	.08	8.90	.98	9
	<i>i</i>	9	3.4	.48	.40	.12	2	2	.25	.00	7.80	1.08	6
	<i>j</i>	10	3.5	.60	.90	.42	8	9	1.15	.18	8.35	.42	8
<i>Subject G</i>	<i>k</i>	1	2.4	.68	.65	.21	4	2	.35	.16	7.10	.72	4
	<i>l</i>	2	2.5	.60	.65	.21	5	4	.60	.12	9.40	1.69	8
	<i>m</i>	3	2.6	.48	.95	.09	7	9	1.25	.30	8.00	1.40	6
	<i>n</i>	4	2.6	.55	1.10	.34	9	8	1.10	.16	6.70	.80	1
	<i>o</i>	5	2.7	.42	.90	.02	6	5	.70	.16	6.90	.93	3
	<i>p</i>	6	3.5	.60	1.60	.45	10	10	1.50	.30	8.30	1.24	7
	<i>q</i>	7	3.6	.80	.48	.20	1	7	.95	.16	6.70	1.26	2
	<i>r</i>	8	3.9	.92	.48	.23	2	3	.35	.16	10.50	1.70	9
	<i>s</i>	9	4.2	.92	.48	.13	3	1	.25	.00	7.40	.98	5
	<i>t</i>	10	4.5	2.55	.95	.19	8	6	.70	.08	11.50	1.60	10

The average threshold values of each point for pain, expressed in terms of the arc of the circle, and also for touch, are given in

vertical columns under Series I. The touch thresholds were obtained by a similar procedure, excepting that the stimulus arm of the balance was extended by attaching the needle to the end of a straw fastened to the balanced beam. The threshold values of the points to the touch stimulus as given in the table are averages of ten sets of experiments on each point. These values are not directly comparable with the pain thresholds owing to the change in the relation of the intensity of the stimulus to the degrees of the circle occasioned by the modification of the apparatus necessary to obtain a subliminal touch stimulus. The relative sensitivity of the points, however, may be compared. In the vertical columns, the table indicates under Series I the order of sensitivity of the twenty points to both pain and touch. It appears that the two orders do not correspond. For example, with subject F point *i*, which is the ninth in order of sensitivity to the liminal pain stimulus, is second in the order of sensitivity to the liminal touch stimulus. Points *c* and *d* are among the most sensitive points to pain, but are seventh and last in order of sensitivity to touch. Points *f*, *h*, and *j* correspond fairly well in relative sensitivity. For subject G there appears even less correspondence. Points *g*, *r*, and *s*, which are the seventh, eighth, and ninth in order of sensitivity to the liminal pain stimulus, are the three most sensitive points to a liminal touch stimulus.

The method used in this experiment was similar to that employed by Singer in experiments reported from the Harvard Psychological Laboratory. [145.] My results are corroborative of those obtained by him.

A second series of experiments with the same twenty points was made with a more delicate apparatus. A very light, delicately balanced metal wheel suspended on pivot bearings was transformed into a balance beam by extending one radial spoke into an arm to which the stimulus could be attached, the opposite radius being weighted exactly to balance the stimulus arm. The apparatus was provided with a graduated arc to record the displacement of the needle arm from the position of

equilibrium and was provided with a device for holding the arm in place and releasing it during the conduct of a single experiment. The apparatus was used without modification to test the twenty points for both touch and pain. All the points were gone over, first at  $\frac{1}{4}^{\circ}$ , then at  $\frac{1}{2}^{\circ}$ , then at  $\frac{3}{4}^{\circ}$ , and so on until the touch threshold had been reached, when the stimulus was increased by stages of  $\frac{1}{2}^{\circ}$  until the pain threshold was reached for each point. The touch and pain thresholds were determined five times for each point, and the averages are recorded in the table under Series II in degrees of the circle. As measured in terms of the arc of the circle the pain thresholds are about ten times greater than the touch thresholds. Looking to the table for the relative sensitivity of the twenty points it is seen that for subject F point *b*, which is the first in order of sensitivity to pain, is sixth in order of sensitivity to touch, and point *i*, which is sixth in order of sensitivity to pain, is second in order of sensitivity to touch. For subject G point *l* is eighth in order of sensitivity to pain and fourth in order of sensitivity to touch; *n* is first and eighth, *q* is second and seventh, *r* is ninth and third, *s* is fifth and first, and *t* is tenth and sixth in order of sensitivity respectively to pain and touch. Comparing the results of Series I and II, for touch and for pain separately, as may be readily done by running the eyes down the columns giving the order of the points with respect to relative sensitivity to touch and pain stimuli as determined in the two series, it is striking that the twenty points correspond in relative sensitivity to touch, and also, though not without some exceptions, in relative sensitivity to pain. But the points do not correspond in their relative sensitivity to touch and pain. These facts are graphically represented in the curves of Figs. 1 and 2. The ten points are laid out upon the line of abscissas at equal distances and in the order of sensitivity to pain, as this was obtained in the second series. The solid line which represents in both figures the threshold values of pain in this series therefore gradually rises from the left to the right. The line of dots represents the threshold values of the same ten points

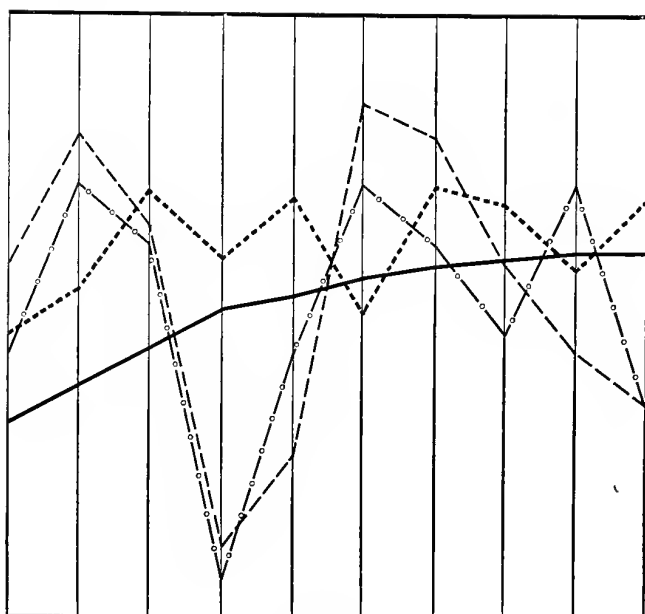


FIG. 1

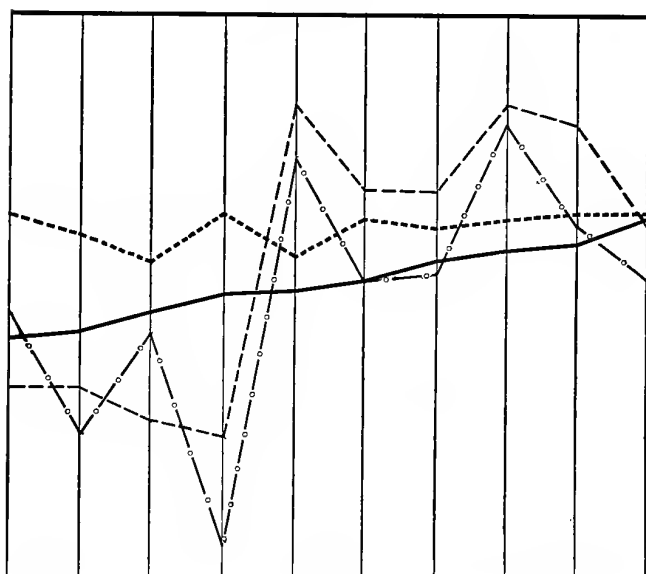


FIG. 2

obtained in Series I. The line of dashes and dots represents the touch thresholds of Series I, and the line of dashes the touch thresholds of Series II. To bring the curves in close juxtaposition, the scale has been taken of different values in the plotting of the several curves; the pain thresholds of Series I are plotted by taking  $.1^\circ$  equal to 1 mm.; those of Series II by taking  $.1^\circ$  equal to .5 mm.; and the thresholds of touch in both series by taking  $.1^\circ$  equal to 5 mm. It is readily seen that the curves of the touch thresholds of each set of ten points are much more nearly parallel than are the curves of pain, and that there is no correspondence at all between the curves of touch on the one hand and those of pain on the other.

These results seem to justify the following conclusions: (1) Points on the surface of the skin have fairly constant thresholds of touch and somewhat more variable, but yet fairly constant, thresholds of pain. (2) Although the same points on the skin are sensitive to both touch and pain, the thresholds of touch and pain appear to have little relation to one another in the case of many of these points.

The most natural interpretation of these results might appear to be the conclusion that there are distinct peripheral end organs of pain, but that this is not the only possible explanation of such facts will be shown in later portions of this discussion.

With the subject H, an attempt was made to ascertain the relative number of the points yielding pain and of those yielding touch at various degrees of stimulation. The area selected was about  $\frac{1}{2}$  inch square, on the volar surface of the forearm. Within this area, four hundred spots were tested at  $1^\circ$ ,  $1\frac{1}{2}^\circ$ , and  $3^\circ$ . The apparatus used was that employed in Series I of the immediately preceding experiments. At  $1^\circ$  only 61 points gave pain; at  $1\frac{1}{2}^\circ$  this number rose to 170; at  $3^\circ$ , to 370. During the last test each point not yielding pain at  $3^\circ$  was subjected to successively increasing stimulation. No analgetic points were found, although three points yielded pain only at a degree of impact sufficient to give the points an inflamed appearance.

These three points were tested on several occasions and gave fairly constant threshold values.

There is no reason to doubt the fact of differences in the sensitivity of various points of the skin to painful stimulation. Blix, who made the first investigation of the skin by the punctiform method, found that here and there a needle could be inserted very deep before pain appeared, whereas other points were so sensitive that a slight pressure called forth pain. [13.] Differences in pain sensitivity were observable also with thermal and electric stimuli. Von Frey found that on the hand alone the pain threshold ranges from 100 to 300 g./mm.<sup>2</sup>. [39.]

Moczutowsky has made careful tests of the pain sensitivity of points included within small areas on various parts of the body, using an algesimeter terminating in a needle with a cross section of 1 mm.<sup>2</sup> and adjustable at heights varying by 1 mm., the depth of its insertion being marked on a graduated scale. From these results he has made a comparative study of the sensitivity of various parts of the periphery of the body. He finds that women are more sensitive to pain than are men; that the left side is more sensitive than the right; that the furrows of skin are more sensitive than the ridges (a fact confirmed by several investigators); that on the face the sensitivity increases from the mouth to the external ear, and from the chin upward, while on the hand it increases from the thumb toward the little finger; that on the dorsal side of the fingers the sensitivity is greater than on the volar side; that over joints and near bones the sensitivity is greater; and that on the forehead the greatest sensitivity is nearest the hair. He found also that the sensitivity to pain does not vary with the sensitivity to touch and temperature, nor with perception of locality. [110.]

The existence, however, of "pain points" in the stricter sense of the term — that is, of discrete points which stand in a specific relation to the pain sense — is a question which is not solved by the demonstration of the differential sensitivity of certain points of the skin to pain and touch. The variations in sensitivity which have been discovered are all capable of

explanation on other grounds than that of the correlation of the specially sensitive points with specific terminal organs of pain.

If it could be shown (1) that there are points which respond to any form of excitation, thermal, chemical, or electric, *with pain only*, and (2) that on other points (heat spots, cold spots, pressure spots) the specific pain sensation cannot be excited, we should then have a local discreteness which might fairly be regarded as significant for the pain sense, and it might be expected that histological investigations of the skin would reveal a true anatomical basis for these pain points.

Von Frey believes that he has discovered discrete pain points of this character. By the use of the bristle stimuli already described and of needle stimuli applied by the method of Blix, he finds on the skin (which he has softened with alkaline preparations in order to limit the stimulation as much as possible to the single point) many "points where light mechanical stimulation gives immediately a strong 'sticking-feeling,' almost or entirely devoid of pressure and contact sensation, which passes into a 'drawing, irradiated,' pain so intense that one involuntarily withdraws the stimulus." These points are most numerous in the furrows of the skin, and respond with pain to electric, thermal, chemical, and mechanical stimulation. "If one first seeks out and marks the heat-spots, cold-spots, and pressure-spots on the area to be investigated, and then goes over the surface with a needle, it will be found that as a rule the cold-spots, heat-spots, and pressure-spots are painless, as well as numerous spots between these." [40.] "On pain-spots the sensation diffuses itself both in area and in depth; in pressure-spots the diffusion is entirely superficial and sharply circumscribed." On the cornea and conjunctiva only pain points are found; the lightest stimulation of any kind calls forth the sensation of pain, unaccompanied by any trace of pressure or temperature. This is particularly significant, for the reason that here nothing but intraepithelial free nerve endings are found. [36.]

A part of the evidence adduced by von Frey for the existence of discrete pain points has been rendered doubtful by the results

of other experimenters. Nagel, for instance, has shown conclusively that the cornea and conjunctiva mediate several sensations. Nagel used sometimes a whalebone probe with a "button"  $\frac{1}{2}$  mm. thick at the end, sometimes a hair stimulus, sometimes a wet brush. On his own cornea a hair stimulus of .08 mm. gave painless pressure, then tickle, then pain (after several seconds). A brush dipped in a six per cent saline solution gave weak contact, on slight pressure. A current of air is perceived as cold. [116.] Donaldson explains von Frey's results by the fact that only pricking stimuli were used. Donaldson's investigations of the temperature sense of the eye give further evidence of the inaccuracy of von Frey's conclusions. [28.]

Ziehen and Dessoir have shown that temperature points are not analgetic. Dessoir, using punctiform mechanical, thermal, and electric stimuli with sixteen subjects, found that a sufficiently strong stimulation would give a sensation of pain on points that had been previously found to be temperature points. [22.]

Goldscheider, in a series of investigations extending over twenty years, believed that he had proved beyond doubt that pressure points are not analgetic. In one of his earlier works Goldscheider speaks of the skin as a "mosaic of specific sensation-points: cold-, heat-, pressure-, and pain-points." [50.] The pain points, he says, do not coincide with the pressure points, "the same stimulus which brings forth the *körniges Gefühl* on pressure-points excites on the pain-points a fine sticking feeling; on most of these points one feels . . . a very weak dull contact which quickly passes into pain. . . . These points are also demonstrable by a weak faradic current." The pain on these points is lancinating. Pressure points, also, may be painfully excited, but the pain is of longer duration and more widely diffused than on other points.

In his later works, Goldscheider abandons the original charts of the topography of pain spots, since he is convinced that "the determination of these points involves sources of error that make it impossible to formulate any laws in regard to them." "In my earlier works," he says, "I designated these as

pain-points, though I did not intend to signify by this name that these points are specific: *I am far from believing that they stand in any special relation to the pain-sense.*" [54.] In *Ueber den Schmerz* (published in 1894), although still holding to the analgesia of temperature points, Goldscheider emphasizes still more strongly his view of the general diffusion of the pain sense. "There are many points on the skin which, if pricked with a needle, do not bleed: ought one on this account to give up the theory of the general distribution of blood-vessels? The proof of minute analgetic spots in no wise demonstrates a discrete apparatus for pain." [56.]

On the whole, there seems to be little evidence for the local discreteness of pain in the sense in which von Frey uses the term. There are none of the established facts that are not explicable on other hypotheses than that of the existence of specific pain points.

A further question connected with the distribution of pain is that of the relation of pain to the various sense organs. Can pain be excited in the optic, auditory, olfactory, gustatory, and thermal, etc., organs and nerves?

The experimental investigation of pain in relation to the optic organ and nerve may be said to date back to Magendie's experiments, in 1824, on the effect of section of the optic nerve and mechanical stimulation of the retina, when it was discovered that in the case of mammals, amphibians, and fishes neither the section of the nerve nor a needle prick on the retina gives pain. Subsequent experimental and pathological investigations have, for the most part, tended to confirm Magendie's view of the analgesia of the neural apparatus of vision. Widmark has reported a number of cases where, although scotoma has been caused by overstimulation from dazzling sunlight, there was yet felt no pain. [40.] The cases of amaurosis with photophobia which are reported by von Walther and others (see Weber, 163) may be explained as due to inflammatory processes which are set up in the conjunctiva—a strictly dermal tissue—rather than to the excitation of any part of the organ of vision itself.

Retinitis is known to be painless. "The auditophobia and photophobia of meningitis are hardly ascribable to the nerves of audition and vision." [172.]

The so-called *Blendungschmerz*, which is often cited as an example of pain in the visual apparatus, may be explained either on the ground of the violent contraction of the pupil, and the consequent irritation of the extremely sensitive iris, or on the hypothesis of a chemical irritation of the rods and cones of the retina, which is not transmitted to the optic nerve and which is a phenomenon of fatigue similar to that which is observable in the muscles. [125.] This fatigue is observable even in cases where the optic nerve is atrophied.

A similar explanation may be made of pains that appear to involve the organs of taste and smell. In these cases there appears to be a chemical disintegration of the dermal tissues of the mouth and tongue rather than an activity of the nervous elements of these special organs of sense. So far as pain from such activities of the sense organs as inharmonious combinations of colors, discordant sounds, and the taste of quinine are concerned, it has already been shown that we have here to do with a confusion of the painful with the disagreeable.

Pain, therefore, does not appear to be excitable in the specific structures of the various sense organs, but only in dermal or other less specialized tissues connected with these organs. This view, moreover, is entirely in accord with the anatomical facts. It has been clearly demonstrated that the ciliary muscles, the choroid, and the iris are supplied by short ciliary nerves coming from the ciliary ganglion and from the nasal portion of the ophthalmic division of the fifth nerve. [35.] The membrane of the tympanum is supplied by a filament of the auriculo-temporal nerve of the inferior maxillary branch of the fifth nerve, and the tensor tympani by fibers from the otic ganglion. Branches from the glosso-pharyngeal nerve are distributed to the mucous lining of the middle ear, one to the Eustachian tube, one to the fenestra rotunda and fenestra ovalis, and one to the mastoid cells. [131.]

Even if it could be demonstrated that the optic and auditory nerves are involved in the so-called light and sound pains, it should be remembered that an explanation of such phenomena may be found in the well-known fact of the diffusion of sensation. The effect of disparate sensations upon one another (as seen, for instance, in colored audition) may account for pains of this class. A nervous excitation may be conceived of as passing from the cerebral center for the representation of the optic nerve to that of the trigeminal nerve.

Although the experimental and pathological evidence in regard to the sensitivity of structures other than the skin and the nervous apparatus of the higher senses, points to the general distribution of pain throughout the body, there is no conclusive evidence that any organ or point mediates pain only. The investigation of the stimulation of pain, therefore, does not lead to the conclusion that the specific or adequate stimulus of pain — the physiological stimulus — requires the functioning of a distinct peripheral organ.

## PART III

### PAIN AS A SPECIFIC DIFFERENTIATION OF SENSE

IN the preceding chapter it was shown that there is no conclusive evidence for the peripheral discreteness of the physiological apparatus of pain. It is necessary now to inquire whether this general distribution of pain is consistent with its discreteness as a sensation. The investigation of this question involves a somewhat closer examination of the nature of a sense quality, and for this purpose it will be necessary to review briefly some of the more important phases in the development of the theory of sensation.

The Aristotelian concept of sensation, according to which the qualities of sense are attributed to differences in the qualities of external objects, prevailed until comparatively recent times. The only respect in which it was felt to be inadequate was in relation to the fact of the specific response of a sense organ to a stimulus other than its usual excitant. The chief facts of this kind known before Müller's time are: flashes of light from mechanical stimulation of the eye (known to Aristotle); electric taste (mentioned by Sulzer in 1752); electric taste, hearing, sight, and touch (Volta, 1800); mechanical, organic, and electrical light and color (Purkinje, 1823); and the sensations of light from section of the optic nerve (Magendie, 1824). [165.]

From time to time various attempts were made to reconcile these facts with the generally accepted theory of the adaptation of sense organs to particular forms of excitation. Hobbes advanced the theory that normal vision is really a mechanical process; the "mechanical sight," therefore, presented no exception to the laws of visual sensation. Purkinje [130] presented the converse theory, that "mechanical sight" is reducible to

normal sight, inasmuch as the mechanical stimulation of the eye really arouses the undulatory movements constituting light. Newton had much earlier explained mechanical sight as due to the excitation in the retina of processes similar to those found in ordinary light sensation. Erhardt Schmid, in 1801, had spoken of "a specific sensibility of the nerves, a capability of certain activities" [140]; and Bell, in 1811, of the fact that "an impression made on two different nerves of sense, though with the same instrument, will produce two distinct sensations, and the ideas resulting will have relation to the organs affected. Piercing the retina with a cataract needle gives a flash of light, and a blow on the head makes the ears ring, and the eye flashes light, but no sound or light are present." [8, 24.]

The first theory in which an attempt was made to systematize and explain the two classes of apparently contradictory facts (*i.e.*, the response of each sense organ to a *particular* stimulus, and its *specific* response to excitations from stimuli other than that to which it is "adapted") was formulated by Johannes Müller and outlined in three works: *Zur vergleichenden Physiologie des Gesichtssinnes* (1826), *Über die phantastischen Gesichtserrscheinungen* (1826), and the *Handbuch der Physiologie* (1837). Müller's theory is psychophysiological, and is a reaction from the purely psychophysical theories of his predecessors. He bases it upon four classes of facts:

1. External agencies can give rise to no kind of sensation which cannot also be produced by internal causes.
2. The same internal cause excites in each sense the sensation peculiar to that sense.
3. The same external cause also gives rise in each sense to the sensation peculiar to that sense.
4. The peculiar sensations of each nerve of sense can be excited by several distinct causes.

Upon these facts Müller bases his thesis that "sensation is not the transmission of a quality or state of an external object to consciousness, but the *transmission of a quality or state of*

*our own sensory nerves to consciousness, occasioned by an external cause, and these qualities differ in the different sensory nerves: they are the sense-energies."* "The nerve sees *itself*, hears *itself*, feels *itself*, smells and tastes *itself*," and not the external object. [111.]

A few words are necessary in regard to the more recent investigations of the facts upon which Müller's theory rests, especially the facts of the specific response of a sense organ or nerve to "inadequate" stimulation.

The main facts cited by Müller concerning the sense of sight have been substantiated. A blow upon the eye is well known to cause flashes or sparks of light; a steady pressure of a small round body upon the eyeball is claimed to excite the sensation of a small white or colored spot in the field of vision, the spot appearing on the side opposite to that stimulated. [10.] Section of the optic nerve excites a momentary flash of light. Electric stimulation of the optic nerve causes the dark field of vision to become bright and whitish violet, the papilla appearing as a dark disk; a stronger current makes the field of vision darker and yellowish gold, the papilla appearing as a blue disk. The color of the papilla Helmholtz explains as due to color contrast. Subjective sight is a frequent phenomenon. ✓

The specific response of the sense of sound to inadequate stimulation has been confirmed by most investigators. Ritter heard, when an electric stimulus was applied to the ear, the G of a violin, at the moment the current was closed. Brenner, with a constant current, heard various sounds, thunder, wheels rolling, clock strokes, etc. [44.] Other investigators speak of a buzzing, droning, or humming in the ear from electric stimulation. Mechanical stimulation of the internal ear, caused by certain diseases of the ear, excites a buzzing or sometimes a ringing. Electric stimulation of the auditory nerve gives sound sensation only when the current is very strong. The sound heard is, according to Dessoir, "the resonance-tone of the conducting apparatus." Subjective sound sensations are well established.

The evidence connected with the sense of smell is conflicting. Johannes Müller observed a smell resembling that of phosphorus when an electric stimulus was applied to the olfactory organ. Rosenthal arrived at no satisfactory conclusions from his experiments in this department, and is inclined to doubt the electric smell. Weber finds no smell excited by thermal stimuli, although he used temperatures ranging from 0° to 50° C. There is little evidence for "mechanical smell." Most persons deny the existence of subjective smells or of smells in dreams, but there are a few authenticated cases of this kind. Lockemann reports the case of a patient whose olfactory tract had suffered injury and who yet experienced smell sensations. [45.]

Some of the most interesting experiments in relation to the specific energy of the nerves have been made in the department of taste. Weinmann regards the "mechanical taste" as doubtful [166]; Bidder and Lewes affirm its existence as independent of the accompanying feeling of nausea which is aroused by compression of the root of the tongue. Valentin found a bitter taste excited by weak mechanical stimulation; Baly a sour taste. Wundt thinks this to be an illusion due to the habitual connection of bitter and sour with nausea. [176.] Henle finds that a delicate current of air gives a salt taste. Most persons have a sweet taste from cold water used as a gargle. A metallic taste is mentioned by one patient as an invariable antecedent of loss of consciousness. The "electric taste" is established beyond question, whatever may be the interpretation given to this fact. If an electric current be passed through the tongue, the positive pole being applied at the tip, and the negative at the nape of the neck, a sour taste is felt at the tip of the tongue. Vintschgau, who has made the most thorough investigation of this subject, finds frequently a sour taste at the cathode and a metallic taste at the anode. [160.] Volta reported a sour taste at the anode, and an alkali taste at the cathode. Taste hallucinations and taste sensations in dreams are exceedingly rare, according to the testimony of most observers.

The question of the specific response of cutaneous sensations to inadequate stimuli will be discussed later in the chapter in connection with the relation of pain to its physiological stimulus.

It cannot be denied that Müller enunciated a great truth, — the fact that the true stimulus of sensation is an intracorporeal process. Like most pioneer thinkers, however, he gives undue prominence to certain phases of his discovery. Throughout his treatises on the subject the chief emphasis is laid upon the “indifference of stimuli,” which Müller thinks is proved by the several classes of facts of response of a sense organ to inadequate stimuli.

The truth is, the response of a sense organ to an inadequate stimulus is the exception and not the rule. It is not true that “the same external cause gives rise, in each sense, to the sensations peculiar to it.” As Fick rightly says, “to establish Müller’s doctrine, twenty series of experiments would be necessary, — each of the five senses being experimented upon by the stimuli of the other senses.” [34.] Such a series of experiments, however, nature is continually making for us, and the results do not bear out Müller’s hypothesis. The eye never responds to heat, nor to sound waves, nor to odoriferous or gustative substances with its specific sensation; we never taste light, nor smell sound, nor touch odors.

Müller’s distinction between stimuli as “adequate” and “inadequate” appears, therefore, to be without a sound scientific basis. The true distinction is one of degree rather than of kind. Some stimuli act upon a sense organ or nerve more directly than others; that is to say, the chain of processes between the extracorporeal process and the psychological state is shorter. It should be remembered, however, that with *any* stimulus, the excitation of the neural process is usually indirect. The sense organ is an intermediary between physical and neural processes, an instrument for the transformation of physical into physiological stimuli. For example, it is probable that the physical temperature stimulus causes an expansion or contraction of a hypothetical “organ” of temperature, or of structures

adjacent to the nerve; and this, in turn, serves as the true physiological stimulus of the sensation of heat or cold. The ether vibrations which are transmitted by the antenervous parts of the eye arouse visual sensations only mediately, that is, by the excitation of photochemical processes in the retina.

Müller's theory, it will be noticed, concerned itself exclusively with the *modalities* of sensation, — sight, hearing, taste, smell, and touch, — and made no attempt to furnish an explanation of the *qualities within modalities*, — the particular colors, tones, smells, etc. The extension of the theory usually referred to as the *Erweiterung* or the "Newer Theory" is an attempt to carry out the doctrine to these qualities. It is impossible within the limits of this monograph to do more than to indicate the chief lines upon which the Newer (or Helmholtzian) Theory has proceeded in the investigation of the several sense departments.

The paradigm of the Newer Theory is found in the sense of hearing. The results of Helmholtz's investigations, in so far as they are connected with the theory of specific energy, may be summarized thus:

The sensation of sound is occasioned by the reaction of the ear to an external stimulus, — vibrations of air. The principal difference between sounds is that between noises and tones, the former being due to non-periodic, the latter to periodic vibrations of air. Noises are mediated by the auditory ciliæ of the ampullæ and the ciliæ of the little bags opposite the otoliths. Tones differ in pitch, force, and timbre, or "quality," depending respectively on the frequency, amplitude, and form of the vibrations. All differences in the pitch, force, and timbre of musical tones are occasioned by differences in the number and arrangement of physically undifferentiated elements, — air vibrations. Qualitative differences in sensation are thus seen to be connected with merely quantitative differences in the stimulus.

So much for the relation of the sensation to its stimulus. Helmholtz's hypothesis as to the nature of the physiological process may be briefly stated in his own words. "When a simple tone is presented to the ear those Corti's arches which

are nearly or exactly in unison with it will be strongly excited, and the rest only slightly, or not at all. Hence, every simple tone of determinate pitch will be felt only by certain nerve fibres, and simple tones of different pitch will excite different fibres. . . . The sensation of a quality of tone would depend upon the power of a given compound tone to set in vibration not only those of Corti's arches which correspond to its prime tone, but also a series of other arches, and hence to excite sensation in several different groups of nerve fibres." Thus both pitch and timbre are traceable to "differences in the nerve fibres which are set in excitation." "This," says Helmholtz, "is a step similar to that taken in a wider field by Johannes Müller in his theory of the specific energies of sense. . . . The ear apprehends vibrations of different periodic time as tones of different pitch. . . . The qualitative difference of pitch and quality of tone is reduced to a difference in the fibres of the nerves receiving the sensation, and for each individual fibre of the nerve there remains only the quantitative differences in the amount of excitement." [71.]

In the department of sight the doctrine of specific energy is illustrated by the theories of color vision. According to the Young-Helmholtz view, the color element of the retina is connected with nerve fibers, sensitive respectively to red, to green, and to violet. The Hering theory of color supposes in the retina three visual substances, which are continually undergoing change. This change may be assimilative (constructive) or dissimilative (destructive). The Helmholtz and the Hering theory of vision illustrate two forms of the theory of specific energy. According to Helmholtz the specificity is structural; according to Hering it is both structural and functional: Helmholtz posits *distinct substances and fibers*; Hering, *substances excitable in different ways*. "The specific energy of a given nervous element," says Hering, "is not a simple power capable of exciting only one form of activity; it is a manifold *Können*." [76.]

In the department of taste the Newer Theory has had many investigators. No satisfactory explanation of the relations of

taste stimuli has yet been found. Chemical composition does not appear to stand always in a direct relation to taste qualities. Both sugar and acetate of lead taste sweet, both quinine and sulphate of magnesia bitter. The acid and saline tastes, however, seem to be related to definite chemical compounds. Nor have any satisfactory results been reached in regard to the relations existing among the taste qualities themselves. Most investigators regard sweet, sour, bitter, salt, as an exhaustive list of simple taste qualities. Wundt is of the opinion that alkaline and metallic tastes are perhaps distinct qualities. Valentin did not regard sour and salt as true taste qualities, but as sensational complexes due to the excitation of nerves of *touch* in connection with nerves of taste. Neumann, Vintschgau, and other recent investigators have found sour and salt to be true taste qualities, coördinate with sweet and bitter. Other taste qualities are probably complexes of these four with touch and smell sensations. An interesting confirmation of the latter theory is found in cases of anosmia, where the patient is still able to distinguish sweet, sour, bitter, salt, but has lost his sensibility to other tastes. [46.]

Kiesow's investigation of the effect of cocaine upon the tongue and mouth cavity shows the discreteness of these four taste qualities. In the case of a weak solution of cocaine he found salt to be but little influenced, but acid to be greatly diminished. Bitter was diminished more than sweet. Bitter he found to disappear entirely when a two per cent cocaine solution was applied five times. He found that salt and sour disappear before "burning" and "biting" sensations, from which he concluded that the latter are touch qualities, not taste qualities. [84.] Shore, in similar investigations with gymnema, found that this anæsthetic produces its greatest effect upon the sensation of sweet; the effect is less with bitter, and little if any with salt and sour. The underside of the tongue near the tip has been usually found to be insensitive to taste. Bitter is felt best at the root of the tongue, sweet at the tip, acid at the margins. Hänig [69] has recently published the results

of an investigation of the sense of taste in which the threshold values for sweet, bitter, sour, and salt are found, for four subjects, in each of the fourteen parts into which he arbitrarily divides the "taste zone" of the tongue. His results show that while sweet, bitter, and sour are perceptible on all parts of the taste zone, each is best perceived in a special region: sweet at the tip, bitter at the root, and acid at the margin. Salt is perceived almost equally well throughout the taste zone.

Hermann, Natanson, Fick, Guyot, and Vintschgau explain the difference in the perception of the taste qualities on different parts of the tongue by the hypothesis of separate nerve fibers for the primary taste qualities. Dessoir [25] and Stumpf reject the hypothesis of different fibers. Wundt even denies the fact of differentiation, and asserts that if the taste stimulus be sufficiently concentrated, every one of the four taste qualities is excitable on each papilla, although papillæ differ in their relative sensitivity to the various tastes. "On anatomical grounds," Wundt says, "it is probable that taste-cells of varying chemical excitability are found in the taste-bulbs. Whether, however, these differences correspond to the four taste qualities, or whether every terminal cell can react in a different way to different impressions and therefore only its capability of reaction toward particular chemical influence is specific, has not yet been determined." [176.] Goldscheider sees in the taste sense a grouping of specific fibers, their specificity consisting in the chemical differentiation of the *Stiftzellen*. He does not regard the four taste qualities as simple sensations, of which all other gustatory sensations are compounded, but rather as "signs" (*Zeichen*) of a collective character: that these four and not others are selected is due to the fact that these appear most frequently and are connected with bodies relatively simple in their chemical constitution. [46.]

There is little to be said in regard to the theory of specific energy as applied to the qualities of smell. Ahronsohn and others have attempted to classify smell qualities, but no satisfactory results have been obtained. That the various qualities

are due to various chemical changes there is little doubt, but whether these changes are due to the action of external stimuli upon *different* chemical substances in the olfactory organ or to the action of different stimuli upon the same chemical substance is not known. It is impossible, of course, to stimulate isolated parts of the organ of smell and thus to determine, as in the sense of taste, whether particular qualities are located in special parts of the organ.

The study of the senses of smell and taste is attended with peculiar difficulties. The two senses react upon one another and both are modified by accompanying touch sensations, so that, to use Wundt's phrase, they may be regarded as "undeveloped senses." For this reason the classification of their qualities can never be attended with the same degree of certainty that attaches to similar classifications in other departments.

The question of the number of sense qualities mediated by the skin dates back as far as Aristotle, who expressed doubt as to whether touch is a single sense, inasmuch as so many pairs of opposites are perceived by it: warm, cold; dry, wet; hard, soft, etc. He concludes that it is not; that we think it a single sense simply because of the common medium. The touch sense, however, is no more *one* (because the medium is the same) than is the "tongue sense" one because by the tongue we both taste and touch. [144.]

The first attempts to differentiate skin sensations concerned themselves chiefly with the qualities of touch and temperature. It is generally agreed that these represent distinct psychoses, but there is still much dispute as to the nature of their physiological differentiation. Weber has attempted to identify them on the ground that a cold object appears heavier, a warm object lighter; a fact that he explains by the hypothesis that these qualities are mediated by the same end organ, and that the contraction caused by the cold object is equivalent to pressure. [164.] Fick and Wunderli conclude, from the same fact, that pressure and temperature sensations differ, not qualitatively, but quantitatively and spatially [33], and therefore agree with

Weber's view as to the identification of the two. Funke, on the other hand, thinks temperature and pressure to be as distinct as sight and sound, and thinks that Weber's results really prove the discreteness of the two sensations, for the reason that changing degrees of temperature interfere with the power of perceiving pressure. [42.] Griffing has recently made some experiments which he regards as conclusive for the differentiation of temperature and pressure. [68.]

The pathological evidence for the discreteness of the two has been given in a preceding chapter, where cases were cited in which the temperature sense was destroyed without impairing the sense of touch.

The most important evidence for their discreteness, however, as well as for the discreteness of heat and cold, is found in the experimental results of Blix, Goldscheider, von Frey, Moczutowsky, and other recent investigators who have used punctiform stimuli. Blix believes the law of specific energy to hold good in cutaneous sensations. Specificity, however, according to Blix, belongs to the peripheral end organs and not to the nerves themselves; the latter function in only one way. There are specific end organs for pressure, for heat, and for cold, demonstrable both with electric and with specific stimuli. [12.]

Goldscheider's results agree, as we have seen, with those of Blix so far as the discreteness of heat, cold, and pressure is concerned. Heat spots, cold spots, and pressure spots give a specific response to electric stimulation. Temperature spots perceive neither contact nor pain. The stimulus process for the temperature nerves lies in the *rising* or *sinking* of the temperature of the skin: when the temperature sinks, the cold nerves are stimulated. The same objective temperature can excite now the one, now the other, temperature sensation. [61.]

Von Frey regards the results of his experimentation on the temperature sensations of the eye as proving the discreteness of heat and cold, inasmuch as he finds that the conjunctiva feels only *cold*. [38.] His results are, however, disputed by Donaldson [28] and Nagel [115], and the point must be regarded as unsettled.

By some investigators the end bulbs of Krause are suggested as the probable end organs of cold, the corpuscles of Rufini as the organs of heat, and the corpuscles of Meissner as the organs of pressure. Because of the difficulty of stimulating isolated points, the determination of the functions of these end organs — whose anatomical discreteness seems fairly well established — is necessarily a slow process, and it cannot be said that indisputable evidence has yet been obtained.

Before taking up the application of the Newer Theory to the phenomenon of pain, a few words may be added to call attention to certain phases of the theory as developed in the several sense departments.

It is important to note that the Newer Theory fully recognizes the fact of the transformation of physical into physiological stimuli. Much of the experimental work of Helmholtz, the originator of the *Erweiterung*, has been devoted to the investigation of physical processes up to where they are transformed into physiological stimuli.<sup>1</sup>

The Helmholtzian theory represents the best working hypothesis that has yet been advanced in the psychology of sensation. The difficulty which Wundt [175], Lewes [92], and Horwicz [78] find in reconciling this theory with the doctrines of modern biology is gratuitous, for the theory is not essentially antagonistic

<sup>1</sup> The *Lehre von den Tonempfindungen* is devoted chiefly to this part of the process. Dessoir and other critics of the Newer Theory, who find an antagonism between the *Mutterlehre* and the *Erweiterung*, on the ground that the latter is an "identity theory," while Müller's doctrine was an "interpretation hypothesis," ignore the fact that Helmholtz regards the organ of Corti and the retinal fibers merely as the organs for the transformation of physical into physiological processes and never affirms the identity of physical vibrations with nervous excitation.

The essential agreement between the *Mutterlehre* and the Helmholtzian doctrine may be seen from the two following statements:

"Sensation is not the conduction of a quality or state of an external object to consciousness, but the conduction of a quality, a state of a sensory nerve to consciousness, occasioned by an external cause, and these qualities are different in the different sense-nerves, — the sense-energies." [111.]

"Our sensations are effects which are brought about in our organism by external causes, and *how* such an effect shall express itself depends, of course, entirely on the kind of apparatus involved." [73.]

to the hypothesis of phylogenetic and ontogenetic development. The specific sense energies are all a product of development. Goldscheider indeed suggests that at one time nerve endings were irritable by the most diverse stimuli (as, for instance, in Nüsslin's hypothesis, certain touch cells of the amphioxus were sensitive to light and sound); the excitations and psychical impressions show no differentiation. Then organs specially sensitive to light arise; also nerves. The animal now no longer *moves* when these are excited; hence to such sensations is given an inner (qualitative) sign. [48.]

In the adult consciousness the sense organs are seen to maintain certain constant relations to particular stimuli. Whether we view this from the biological standpoint and call it an "adaptation of sense organs to stimuli," or from the psychophysiological standpoint and speak of an "electivity of the sense organs," is immaterial. The fact that sensations are determined by the character of our nervous apparatus is entirely consistent with the biological theory that the senses are the product of the action of external vibrations upon the organism.

If the differentiation of the nervous system is thus conditioned by environmental influences, it is easy to see that it is only approximately fixed and permanent. Sense energies are not specific in the sense of being absolutely static.

It should be remembered, moreover, that any given sensational experience involves the activity of other parts of the nervous system than the one which gives to it its predominant tone. *The physiological correlate of a sensation is as much of an abstraction as is the sensation itself.* Just as we never have a sensation of red unmixed with other sensational and associative elements, so we never experience the activity of an isolated group of sensory neurons. The neural activity resultant upon the vibration of a fiber of the basilar membrane must be conceived of as accompanied by physiological reverberations which affect all parts of the system more or less, as a pebble disturbs the equilibrium of a large pond. I need only cite such instances as colored audition and other *Mitempfindungen* to illustrate the

possible diffusion of the physiological processes incident upon the simplest stimulation. Every psychosis is correlated with a complex of nervous processes: just as, by abstraction, we can analyze out one part of the psychosis and call it a "sensation," so, by a similar process of abstraction, we may analyze out of the physiological complex one part which is the "fundamental" of a physiological "clang." It is by such a process, for instance, that in the sense of taste we ascribe that psychical product of abstraction "bitter" to the physiological abstraction "gustatory apparatus," eliminating, by analysis, the tactile and muscular contributions to the complex.

The preceding considerations may be summed up thus: While the different qualities of sensation are attributable to the differentiation of physiological processes rather than to that of physical (extracorporeal) stimuli, this differentiation is itself the result of the action of physical agents, and there is therefore an *adaptation* of sense organs to particular stimuli. The physiological differentiation is, further, only approximately fixed and stable, slight changes being observable even in the lifetime of the individual. Finally, the simplest psychical experience involves more than one sense apparatus. The concept of a sensation related to a specific physiological process *is, therefore, an abstraction of psychophysiological analysis.*

It is nevertheless appropriate to raise the question "Can a sensation be related specifically to any one part of a conceptually isolated physiological process rather than to another?" Histological investigation has little to offer toward an answer to this question. End organs, it is true, present striking differences, but we have seen that the end organ is merely an agent for the transmission of inefficacious into efficacious stimuli. Pflüger has shown that all sensory nerves have the same vibration rates. The weight of evidence at the present time seems to justify the Helmholtzian notion of the nerve as not unlike a wire which "conducts one kind of electric current and no other; it may be stronger, it may be weaker; it may move in either direction; it has no other qualitative differences. Nevertheless,

according to the different kinds of apparatus with which we provide its terminations, we can send telegraphic dispatches, ring bells, explode mines, etc. . . . The condition of excitement that can be produced in nerves, and is conducted by them, is, so far as it can be recognized in isolated fibres of a nerve, everywhere the same, but when it is brought to various parts of the brain or of the body, it produces motion, secretions of glands, . . . sensations of light, hearing, etc." [72.]

The evidence based upon the specific action of certain drugs is likewise inconclusive. Nicotine has a marked effect upon hearing, atropine and santonin upon sight, and ergotine upon touch. Experiments with these drugs prove the differentiation of the various sense modalities and qualities (santonin affects the sensitivity to violet especially), but have no bearing upon the question of the *seat* of the specificity, since the conditions of experimentation do not restrict the action of the drug to either the brain, the nerve, or the end organ. The unsatisfactory character of these experiments is seen in the fact that while Arndt uses them to prove the nerve to be the seat of specificity, they have been used by others to show that specificity is resident in the end organ. [2.]

Munk's hypothesis of the localization of sensations in circumscribed cortical areas has been sometimes erroneously regarded as a demonstration of the theory that the brain center is the seat of the specific sense energies. That the extirpation of the occipital lobe destroys sight may be due merely to its *connection with the optic nerve and retina*, and its specificity may thus be purely a local one. The two questions — the seat of sensations and the seat of the specificity of sensations — are distinct.

The sight hallucinations of the blind and the whole class of subjective sensations, including synæsthesias, have been thought to furnish evidence for the ascription of the specificity of the senses to the brain centers. [4.] Goldscheider, for instance, reports a case of sight hallucinations in a patient whose entire optic nerve was atrophied. Zaufal reports an interesting case of synæsthesia: a blind musician, very deaf in the left ear,

could hear the note C very clearly, to the left, when his fingers were rubbed together. [49.] This is not unlike a case of synæsthesia mentioned by Whipple, in which certain musical notes were associated with particular intensities of pain from the algometer. [167.]

Urbantschitsch [157] describes a painstaking investigation of the influence of sensations upon one another. During a constant stimulation of one sense department other departments were stimulated at intervals, and the effect on the former noted. In all cases he found changes, greater or less, and some of the results are very striking. The tickle sensation, for instance, is decreased by low tones, increased by high tones. Pain (from a heat stimulus) is decreased by dim light or by yellow and blue; increased by bright light or by green or red. In some cases an intense heat or cold stimulus on one part of the body diminished the tactile sensibility on a distant part of the body.

The seat of the specificity of a sensation appears, therefore, to be the *entire sense substrate*, and not any one part. If the nervous process be conceived of as a disturbance of equilibrium and an effort to restore equilibrium, it is evident that the character of this effort must depend upon the character of the entire apparatus involved. Lotze has given an excellent illustration of this: "Just as the attachment and tension of a string between two end points determines its vibration rate and therefore its pitch, so we can conceive, between the two end-points of its course, in each nerve, a certain particular form and degree of tension, which depends on the kind of ending in the center and in the sense-organ. . . . So long as a sense-organ, its nerve-fibres and its central endings are normally connected, they form a closed system . . . which, stimulated at any point, must always answer by a reaction corresponding to its specific *Stimmung* and differing from the reaction obtainable from other closed systems of a different *Stimmung*." [93.]

This discussion of the specificity of sensations has been introduced for the purpose of showing the standpoint from which

the study of pain as a psychophysical fact must proceed. If pain represents, as I have tried to show, not a mere "aspect" of sensations, nor an "attitude" toward sensations, but a distinct sense modality, — a "content," — the ground of its specificity is to be sought in the constitution of its physiological correlate, even though that physiological correlate is, like the correlates of other senses, only approximately distinct.

There is little evidence in favor of the existence of a peripheral organ of pain. The intraepithelial free nerve endings were suggested by von Frey as the organ of pain, chiefly on the ground that on the cornea, where pain is the only form of sensibility, only these endings are found; but, as we have seen, subsequent investigation has shown von Frey's results to be inaccurate. The most careful histological investigation of the skin is that made by Goldscheider, who marked carefully the pressure, cold, and heat spots, and then extirpated bits of the skin 1–1.2 mm. in length, .5–.7 in width, and 1–1.3 thick. [53.] In the course of this investigation Goldscheider found nothing to lead to a change of his contention, that the difference in the sensitivity of spots on the skin has no significance for an organ of pain. The partial anæsthesias from the peripheral or local application of cocaine and other anæsthetics have been thought to offer evidence of specific end organs of pain, but that these facts are capable of explanation on another hypothesis will appear later.

I shall not enter into a discussion of the pathological and experimental evidence which has been brought forward in connection with the question of a cortical center of pain. A few of the most significant cases have been cited in other parts of this monograph. Edinger [31], Claiborne [19], and others report cases of "subjective pain," which would seem to indicate a cortical center. There is no reliable evidence as to the locality of such a center, but this does not "make the assumption of the existence of a pain center any more remote than is the localization of centers of other sensations. It is only in the roughest way that cortical physiologists are able to locate

visual, auditory, somæsthetic, taste, and olfactory areas. We know absolutely nothing as yet of the different localities in which are to be found those cells whose functioning conditions the consciousness of the various qualities of sound, color, taste, smell, heat, cold, and touch. It is my opinion that we are as much justified in a tentative assumption of the existence of a pain center as in that of a center for any other specific quality of sensation." [Witmer, 173.]

I pass now to the most important physiological evidence connected with the pain sense: *the pathological and experimental facts which indicate a special conduction tract in the spinal cord.*

Schiff [141], Brown-Séquard [16], and others have investigated the effect upon sensation of partial sectioning of the spinal cord. Partial section of the white fibers of the cord results in insensibility to tactile impressions, — anæsthesia and paralysis of voluntary motion. Section of the gray substance results in analgesia — a condition in which touch sensations remain but pain is not felt. It is worthy of note that while the effect of section of the white fibers is limited to particular parts of the body, "section of the gray matter is not thus limited in its effects, which extend, though with some irregularity, to all parts of the body supplied by nerves which enter the cord below the section; and it is the more complete according as the section has included more of the gray substance." [77.] This view has had many supporters, among them Wundt and Goldscheider and Funke.

An important contribution was made to the anatomical evidence in favor of the significance of the gray matter for pain by Adam Ciaglinski in 1896. Ciaglinski announced the discovery of a long sensory tract in the gray matter. According to Ciaglinski, as reported by Gordinier [63], "this tract of fibers is somewhat pyramidal in shape on transverse section, and is located, . . . in the gray commissure between the ventral border of the posterior columns and the central canal. It has been traced from the lumbar cord to the cervical enlargement.

Ciaglinski believes its fibers to come from the posterior nerve-roots, and thinks that it may conduct sensations of pain and temperature."

It is a disputed question whether the pain conduction is "crossed" or "uncrossed" in the spinal cord. Much of the evidence given by Turner, Mott, Bottarzi, and other investigators of this question is based upon the results of vivisection; and, as Dessoir has demonstrated by actual experiment, such evidence is to be received with great caution, for the reason that in the lower animals violent reactions accompany any unusual stimulation, whether painful or not. [26.] Another doubtful point is whether pain is conducted *exclusively* in the gray matter or whether the lateral tract is also involved. The most important recent contribution to the study of these two questions is that of Laehr, who bases his conclusions upon clinical and pathological investigations. Laehr gives an exhaustive study of the disturbances of pain and temperature that accompany certain diseases of the spinal cord. On the basis of this evidence, Laehr concludes that in man the tracts for pain and temperature enter the posterior horn on the same side, but cross as they continue their course through the gray matter. [86.]

The disturbances in the pain sense which are present in syringomyelia and other diseases involving the gray matter of the cord form a large part of the pathological evidence for the hypothesis just given. Another significant class of phenomena is that of the hyperalgesia of the skin in diseases of the visceral organs. Goldscheider and Head believe that hyperalgesia in these cases is explained on the ground that the nerves conducting the pain of the skin area involved are derived from the same spinal segment as the sympathetic nerves of the visceral part affected. Head has mapped out the skin areas corresponding to each spinal segment. Brown-Séquard attributes all referred pains to spinal hyperalgesia. "One might feel inclined," says Goldscheider, "to ridicule the idea that the cause of the pain of an ingrowing nail is the hyperalgesia of a cell-group in the spinal cord. But morphologically as well as

functionally the ganglion-cell is closely connected with the seat of inflammation. The axis-cylinder of the peripheral sensory nerve is . . . a part of the spinal ganglion-cell whose centripetal branches connect with the cells of the posterior horn either directly or through their collaterals. The functional excitation spreads so rapidly that the posterior cells are affected immediately." [58.]

On p. 19 of Part I, mention was made of the *delay* observable in the pain sensation. Beau estimates that pain appears .7 second later than the tactile impression in the case of mechanical stimulation. Burekhardt investigated the rapidity of transmission in the cord and found it to be 12.9 m. per second for painful impressions, while it is 43.3 m. for others. [133.] Dessoir has made a series of experiments to test the time of appearance of tactile, thermal, and painful sensations. With a heat stimulus of  $+40^{\circ}\text{C}$ . there is .6 second interval between the touch sensation and the heat sensation; and from 7 seconds down to .1 second interval between the heat and the pain sensation. [27.]

Richet tested experimentally the delay in the pain sensation by means of a delicate pair of pincers constructed for this purpose. The pincers were applied to the skin with as rapid a pressure as possible up to the time when the pressure was felt to be intense; then no increase of pressure was exerted. "After a short interval pain, which had not been present before, began to appear. It came on gradually, as if in waves. At each second, there is a painful *élancement*, more painful than its predecessor, until the pain becomes unendurable. The pressure has been in no wise augmented: it is the same excitation, which, because of summation, ends in arousing pain." [136.]

The phenomenon of delay has an important significance for the spinal conduction of pain. Schiff found that the more a partial section of the spinal cord involves the gray matter, the greater is the delay in the pain sensation. Goldscheider reports a series of experiments with a patient suffering from a disease involving the gray matter. The average reaction time, as

indicated by the Grunmach polygraph, was .34 second for pressure, while for pain it was 1.2–1.8 seconds. [60.] Cruveilhier, Leyden, Naunyn, Mitchell, and Goltz report similar cases of increased delay in pain in diseases affecting the gray matter.

The evidence, which is more amply reported by Laehr [86] and Witmer [174] than I have thought necessary for the present discussion, is conclusive in its indications of a specific sense substrate of pain in the spinal cord, extending upward probably through the optic thalamus and internal capsules to some as yet unknown region of the cortex. The discovery of all the anatomical elements of the specific pain process and the more exact localization of this central pain organ must be left to the newer methods of histological physiology and pathology.

The first step toward a theory of the relation which the "pain tract" bears to the other sensory paths of the 'cord proceeded from the hypothesis — made highly probable by clinical and anatomical investigations — that the path through the cellular network of the gray substance offers a greater resistance than do the other paths of the cord. Accordingly it is held by Wundt, Funke, and others that stimuli of moderate intensity are conducted over the "long path" of the spinal cord; this path is capable only of a certain degree of excitation, and when the maximum is reached the stimulus "breaks through" into the gray path, which is not accessible to weaker stimuli. If the gray substance is sectioned, pain disappears, for the reason that the white substance is incapable of the excitation necessary to produce the sensation.

A new light has been thrown upon this entire subject within the last ten years by the investigations of Gad and Goldscheider of secondary sensations and "rhythmic" pains. Richet and others had long before demonstrated the fact that stimuli which in a widely separated series produce no sensation will sometimes give pain if the interval be decreased. Naunyn in 1889 published the results of an investigation of pain from intermittent stimuli. He found that patients suffering from *tabes dorsalis* could be made to feel pain from light stimulation

with a pencil, a needle point, the head of a needle, or an electric current, if the stimuli were *periodically* applied. [119.] Similar results are reported by other investigators.

Gad's and Goldscheider's investigations proceeded from the well-known fact of the frequency with which *painful* after-images succeed primary sensations not painful. [62.] In the case of an electric stimulus, a single stimulation does not produce this secondary sensation, but two, or usually more, applications are necessary. The intensity of the painful secondary sensation varies with the intervals of the stimulations. In a series of four stimuli at intervals of from 30 to 60  $\sigma$  this was brought out very clearly.

There is some reason for believing that in these phenomena we have merely the normal pain process, and that every pain may be regarded as a summation phenomenon. The only difference between the cases just cited and ordinary cases of pain lies in the fact that in the former the interval is longer. The pain stimulus consists of a number of stimuli, any one of which, taken singly, produces the sensation of touch only, but, in summation, overflow into the pain tract and produce the sensation of pain.

The hypothesis of summation furnishes a satisfactory explanation of nearly all the important facts of pain, although the evidence upon which it is based is of that "circumstantial" kind which, with our present knowledge of the structure and functions of the nervous system, forms so large a part of the theory of the sense energies.

The principal conclusions of this investigation may be summarized thus:

1. The analysis of judgments of pain shows that pain presents as a psychical state the same distinctness and discreteness which characterize the "typical" sensations.
2. A comparison of pain judgments with judgments of other sensations shows that no distinction can be made between pain and other sensations on the ground of the "non-localizability" and "subjectivity" sometimes attributed to pain.

3. Pain judgments, like judgments in other sense departments, always involve physical and physiological references. There is no evidence that pain is viewed as an aspect, or as a "primary *quale*," of sensation.

4. Though there are manifest differences in the pain sensitivity of points of the skin, and of larger areas and internal organs, there is no indisputable evidence of the existence of specific pain points indicative of a discrete peripheral organ of pain.

5. If the quality of a sensation can be correlated with a differentiation of the sense substance, pain represents such a differentiation, inasmuch as there is evidence that in some part of its neural pathway of conduction, probably in the spinal cord, the sense substance, which is the physical basis of pain, constitutes a discrete and specific central organ of pain.



## APPENDIX

### CONDENSED RECORD OF GENERAL JUDGMENTS IN RESPONSE TO UNKNOWN STIMULI

ABOUT one hundred different stimuli were applied to the skin of the hand and wrist of five subjects, the stimulated part being hidden from the subject's view by a screen. The stimuli included among others, whose character may be ascertained by referring to the schedules given below, needles, metallic disks of various diameters, points of the *æsthesiometer* (dull and sharp), card edges (continuous and notched), wooden surfaces of different shapes and dimensions, etc. These stimuli were applied under different conditions: wet and dry; hot, cold, and indifferent; moving, stationary; constant, intermittent; and (in the case of temperature stimuli) with and without contact with the skin. Painful stimuli were irregularly interspersed among non-painful stimuli. The number of applications of a given stimulus varied from one to twenty; the total number of experiments made upon three subjects was nearly one thousand. The object of the experiments was to obtain data for a comparison of pain judgments with judgments of other sensations, under identical conditions of ignorance on the part of the subject as to the nature of the stimuli, and without any more definite directions to the subjects than to report "what was felt" as a result of the stimulation. The experiments are necessarily inexact, but they probably represent the best that can be accomplished by experimental introspection without enforced sensation categories. The schedules given below summarize and condense the records of these experiments.

Under Schedule A are reported forty-three judgments of three subjects, A, B, and C, in response to stimuli that were intended to be and were shown by the resultant judgment to have been distinctly supraliminal pain stimuli. These judgments are discussed in Part I, Chap. I, pp. 6-9.

Under Schedule B are reported sixty-eight judgments of two subjects, A and B, in response to thirty-four stimuli that were distinctly below the threshold of pain, and were therefore stimuli of other sensations and perceptions. As it is impossible to report the full record of this series of experiments, involving as it does so many individual judgments, Schedule B records the most frequent judgment in cases where the stimulus was applied many times and substantially the same judgment was often repeated; and the first of the judgments is arbitrarily selected for reporting, where the same stimulus was less frequently applied or the judgments were more variable. These judgments are discussed in Part I, Chap. III, pp. 21 f.

#### Schedule A. Judgments of Supraliminal Pain Stimuli

1. **Stimulus.** — Needle point at the temperature of the room.

**Judgments.** — **SUBJECT A:** *Judgment No. 1.* A sharp point; painful here (indicated with the tip of the finger and localized correctly). *Judgment No. 2.* Something sharp; painful here (localized correctly). **SUBJECT B:** Sharp; painful (localized correctly). **SUBJECT C:** *Judgment No. 1.* Sharp; painful prick. *Judgment No. 2.* Sharp, sticking pain; no temperature, but think it was heated. *Judgment No. 3.* Sharp, sticking pain, middle line of back of hand, near wrist (localized correctly).

2. **Stimulus.** — Heated needle point.

**Judgments.** — **SUBJECT A:** *Judgment No. 1.* Heat; painful here (localized correctly). *Judgment No. 2.* Hot needle point; slightly painful (localized correctly). **SUBJECT B:** Sharp; no, not sharp,—bigger than pencil point; painful. **SUBJECT C:** *Judgment No. 1.* Distinctly painful; no temperature, but think the needle was hot; not a sharp, sticking pain, but more diffused,—something like “körniges Gefühl”;  $\frac{1}{8}$  inch diam.; under the skin. *Judgment No. 2.* Pricking sensation and painful; no temperature. *Judgment No. 3.* Painful pricking; also heat pain, though no heat about it; strictly circumscribed pain area under surface of skin as well as on surface. *Judgment No. 4.* Touch without pricking sensation; a little afterglow of pain; no temperature;

probably heat pain. *Judgment No. 5.* Sharp, painful prick; hot, but the heat is not painful, — it is only the prick that is painful. *Judgment No. 6.* Very sharp, intense heat pain, but no sensation of heat itself. *Judgment No. 7.* Sharp, pricking pain; no heat. *Judgment No. 8.* Sharp, sticking pain on same spot (correctly localized). *Judgment No. 9.* Touch, mild, diffused; it left an after-suggestion of pain; I expected temperature sensation, but felt no temperature.

**3. Stimulus.** — Cooled needle point.

**Judgments.** — **SUBJECT A:** *Judgment No. 1.* End of dividers (æsthesiometer); hot; not very painful. (Vigorous reaction.) *Judgment No. 2.* Something hot; pain, but heat was felt first; an after-image: pain touch. (Vigorous reaction.) *Judgment No. 3.* An area of  $\frac{1}{4}$  inch diam. (stimulated); very hot; very painful (localized correctly). (Vigorous reaction.) *Judgment No. 4.* One point of dividers; hot; painful (localized correctly). *Judgment No. 5.* Needle point; hot; painful (localized correctly). *Judgment No. 6.* One point of dividers; hot; painful (localized correctly). **SUBJECT B:** Burned or scratched; painful.

**4. Stimulus.** — Single point of æsthesiometer (sharp). Unheated.

**Judgment.** — **SUBJECT C:** Very sharp, pricking pain; no heat sensation, but I know stimulus was heated.

**5. Stimulus.** — Single point of æsthesiometer (heated).

**Judgment.** — **SUBJECT C:** Very sharp heat pain; felt prick of needle; heat sensation.

**6. Stimulus.** — Moving point. Distance = 10 mm. Hot.

**Judgments.** — **SUBJECT B:** *Judgment No. 1.* A very sharp point; hot; painful; sharp, clutching feeling that goes down into fingers; hand feels paralyzed (localized correctly). *Judgment No. 2.* A hot needle; painful; at first the touch was sharp, then it "slanted"; moved  $1\frac{1}{2}$  inches (localized at middle of path).

**7. Stimulus.** — Æsthesiometer, two sharp points, 50 mm. apart.

**Judgment.** — **SUBJECT A:** Two very sharp points,  $1\frac{1}{2}$  inches apart; painful (localized halfway between).

8. **Stimulus.** — Æsthesiometer, two sharp points, 30 mm. apart.  
**Judgment.** — SUBJECT A: Two points,  $\frac{3}{4}$  inch apart; upper, sharper; upper, painful (localized incorrectly).
9. **Stimulus.** — Æsthesiometer, two dull points, 40 mm. apart.  
Heated.  
**Judgments.** — SUBJECT A: *Judgment No. 1.* One point of dividers; very hot (localized halfway between the two points). *Judgment No. 2.* Needle point; hot; painful (localized at one of the points). *Judgment No. 3.* Hot; painful (localized at one point). *Judgment No. 4.* End of dividers; very hot; painful (localized halfway between points).
10. **Stimulus.** — Æsthesiometer, two dull points, 20 mm. apart.  
Heated.  
**Judgment.** — SUBJECT C: Very sharp, biting sensation at the middle of back of hand; heat pain, but no temperature sensation.
11. **Stimulus.** — Æsthesiometer, two dull points, 15 mm. apart.  
Heated.  
**Judgment.** — SUBJECT C: Sharp, pricking pain, due to heat.
12. **Stimulus.** — Æsthesiometer, two dull points, 10 mm. apart.  
Heated.  
**Judgment.** — SUBJECT C: Sharp, pricking sensation; heat pain; I knew it was heat pain from the way in which it lasted.
13. **Stimulus.** — Metallic disk, 2 mm. diam.; hot.  
**Judgments.** — SUBJECT A: Something as large as a sharpened pencil; hot; slightly painful. SUBJECT C: *Judgment No. 1.* Sharp, pricking pain; no heat. *Judgment No. 2.* Sharp, pricking pain; no heat.
14. **Stimulus.** — Surface,  $10 \times 3$  mm.; wet, hot, stationary.  
**Judgment.** — SUBJECT B: A point; it burned; hot; painful.
15. **Stimulus.** — Metallic disk, 18 mm. diam.; heated.  
**Judgment.** — SUBJECT A: Large area stimulated,  $\frac{3}{4}$  inch diam.; hot; painful; here (localized correctly).

## Schedule B. Judgments of Non-Painful Stimuli

1. **Stimulus.** — One point (sharp) of æsthesiometer.

**Judgments.** — SUBJECT A: Pencil point, not very sharp; seemed to go down gradually. (In some experiments subject spoke of two touches — a point and a vague diffused touch.) SUBJECT B: A sharp point; quick touch; some pressure; hot; am not sure about after-image.

2. **Stimulus.** — One point (dull) of æsthesiometer.

**Judgments.** — SUBJECT A: One sharp point; I felt also contact with a large surface about 3 inches away (this was incorrect) (localized correctly). (In other experiments with this stimulus the subject frequently said "two points.") SUBJECT B: Small, not sharp; no idea of shape; seemed to "glance"; a warm, quick touch.

3. **Stimulus.** — A point; moving.

**Judgments.** — SUBJECT A: Pencil point; hot; moved (locality and direction right). SUBJECT B: Something finely pointed; dragged one surface about  $\frac{3}{4}$  inch (location wrong; direction right).

4. **Stimulus.** — A point; hot, stationary.

**Judgments.** — SUBJECT A: Sharp pencil point; warm, dry (localized correctly). SUBJECT B: A hot point (localized correctly).

5. **Stimulus.** — A point; hot, moving. Distance = 10 mm.

**Judgments.** — SUBJECT A: Point; slightly warm; moved  $\frac{1}{2}$  inch (localized nearly correctly; direction right). SUBJECT B: A warm point; moved quickly 1 inch or less (localized wrong).

6. **Stimulus.** — A point; cold, stationary.

**Judgments.** — SUBJECT A: Circle,  $\frac{1}{2}$  inch diam.; cold, not wet. SUBJECT B: A cold, big, soft object; quick; a square with rounded corners 1 inch across.

7. **Stimulus.** — A point; cold, moving. Distance = 10 mm.

**Judgments.** — SUBJECT A: Area with diam. of  $\frac{1}{2}$  inch; cool, dry (localized correctly). SUBJECT B: A blunt point; cold; moved  $\frac{3}{4}$  inch.

8. **Stimulus.** — A point; wet, hot, stationary.  
**Judgments.** — **SUBJECT A:** Hot pencil point (localized correctly).  
**SUBJECT B:** A blunt edge; dragged over surface  $\frac{3}{4}$  inch (localized right).
9. **Stimulus.** — A point; wet, hot, moving. Distance = 10 mm.  
**Judgments.** — **SUBJECT A:** Delicate point, moved 1 or 2 inches; warm, wet (nearly correct localization). **SUBJECT B:** Small object; moved 2 inches; either touched, discontinuously, or moved very lightly.
10. **Stimulus.** — A point; wet, cold, stationary.  
**Judgments.** — **SUBJECT A:** Something cool, wet,  $\frac{1}{4}$  inch diam. (localized right). **SUBJECT B:** Circle, 3 or 4 inches diam.; hard, cool (location and direction right).
11. **Stimulus.** — A point; wet, cold, moving.  
**Judgments.** — **SUBJECT A:** Cool pencil point; moved  $\frac{3}{4}$  inch; not wet (localized wrong; direction right). **SUBJECT B:** Back of knife blade; moved 1 inch; cold (location and direction right).
12. **Stimulus.** — Hair on skin touched so that it moves.  
**Judgments.** — **SUBJECT A:** Lightest possible touch, as if a hair had been touched. **SUBJECT B:** Something like a small fly bent a few hairs and moved toward my wrist about 1 inch (location included area stimulated).
13. **Stimulus.** — Tickling stimulus; moved about 10 mm.  
**Judgments.** — **SUBJECT A:** Very light tickling sensation. **SUBJECT B:** Something like a centipede; moved  $1\frac{1}{2}$  inches down (location wrong).
14. **Stimulus.** — *Æsthesiometer*, two points (sharp), 44 mm. apart.  
**Judgments.** — **SUBJECT A:** Two points; the lower is the sharper; 2 inches apart (localized incorrectly). **SUBJECT B:** One sharp point; a blunter object 2 inches away; warm, especially the point (location right).
15. **Stimulus.** — *Æsthesiometer*, two points (dull), 40 mm. apart.  
**Judgments.** — **SUBJECT A:** Two blunt touches, one felt like a touch from the blunt end of a pencil; the other was much more vague and larger. **SUBJECT B:** A long object laid on, 1 or  $1\frac{1}{2}$  inches long; thick, cool.

16. **Stimulus.** — *Æsthesiometer*, two points (sharp), 50 mm. apart.  
**Judgments.** — SUBJECT A: One sharp point; something dull 2 inches away (location nearly right). SUBJECT B: One sharp point; a larger object 1 inch away, like end of finger; the point is hot (location wrong).
17. **Stimulus.** — *Æsthesiometer*, two points (dull), 50 mm. apart.  
**Judgments.** — SUBJECT A: Two points; the lower is sharper and penetrating (localized correctly). SUBJECT B: One point; bigger, rounded thing 2 inches farther up ( $1\frac{1}{2}$  inches diam.); the point rather warm (location right).
18. **Stimulus.** — Notched card, 30 mm.; three points in straight line; distance between every two points = 15 mm.  
**Judgments.** — SUBJECT A: Two points of dividers, 1 inch apart; slightly warm (localized incorrectly). SUBJECT B: Rather dull point; some pressure; rather warm (localized at middle point).
19. **Stimulus.** — Notched card, three points in straight line; distance between points = 25 mm.  
**Judgments.** — SUBJECT A: Two points 2 inches apart; one point hot (localized correctly). SUBJECT B: A dull pencil point; slight pressure; warm (located at middle point).
20. **Stimulus.** — Notched card, five points; distance between every two points = 7.5 mm.  
**Judgments.** — SUBJECT A: Large warm circular object touching with slightest contact; the middle part of the object did not touch; I felt also a light touch at one side (localized at middle point of card). SUBJECT B: Something convex or else soft; no sharp edges; indefinite area; rather circular (located correctly).
21. **Stimulus.** — Continuous card edge, 30 mm. long.  
**Judgments.** — SUBJECT A: Surface of vague outline; about  $\frac{1}{2}$  inch diam.; more like a circle than anything else; colder than any previous contact (localized "center of circle" in middle of line of card edge). SUBJECT B: Something like end of thumb; pencil point about 2 inches farther away; both warm.

22. **Stimulus.** — Continuous card edge, 50 mm. long.

**Judgments.** — **SUBJECT A:** Circle, vague in outline,  $\frac{1}{2}$  inch perhaps diam. (localized "center of circle" in middle of line of card edge). (A nearly always judged card edge either as "circle" or as "two vague contacts"). **SUBJECT B:** Two blunt points and connecting line; like a dumb-bell projected on a flat surface; each end of the size of a finger tip (localized correctly).

23. **Stimulus.** — Metallic disk, 2 mm. diam.

**Judgments.** — **SUBJECT A:** Vague object as large as the end of a finger (localized correctly). **SUBJECT B:** A touch; something big, soft,  $\frac{1}{2}$  inch diam.; more intense in center than edges.

24. **Stimulus.** — Metallic disk, 5 mm. diam.

**Judgments.** — **SUBJECT A:** Something circular,  $\frac{1}{2}$  inch diam. **SUBJECT B:** Bigger than preceding touch (localized correctly).

25. **Stimulus.** — Metallic disk, 18 mm. diam.

**Judgments.** — **SUBJECT A:** A "diffuse" area, 1 inch diam., colder than the hand (localized correctly). **SUBJECT B:** Bigger than preceding; cooler and harder (localized correctly).

26. **Stimulus.** — Metallic disk, 2 mm. diam.; heated; no contact.

**Judgments.** — **SUBJECT A:** (Nothing was noticed after prolonged stimulation.) **SUBJECT B:** Touched a hair (localized correctly).

27. **Stimulus.** — Metallic disk, 5 mm. diam.; heated; no contact.

**Judgments.** — **SUBJECT A:** Circular area, 2 mm. diam.; heat (localized correctly). **SUBJECT B:** Hot; diffused, irregular area; perhaps a hair touched.

28. **Stimulus.** — Metallic disk, 18 mm. diam.; heated; no contact.

**Judgments.** — **SUBJECT A:** Light contact; hot; continuing; not painful. **SUBJECT B:** Something drawn over hairs; soft, just touching; bending hairs; moving (this stimulus was 15 mm.).

29. **Stimulus.** — Metallic disk, 2 mm. diam.; cooled.  
**Judgments.** — SUBJECT A: Something cold,  $\frac{1}{2}$  inch diam. (localized correctly). SUBJECT B:  $1\frac{1}{2}$  inches diam.; diffuse touch; cool (localized correctly); after-image: cold, diffuse touch.
30. **Stimulus.** — Metallic disk, 5 mm. diam.; cooled.  
**Judgments.** — SUBJECT A: Cold water on the hand (this was true) (localized correctly). SUBJECT B:  $\frac{1}{2}$  inch diam.; soft; touched hair; cold after-image (localized correctly).
31. **Stimulus.** — Metallic disk, 15 to 18 mm. diam.; cooled.  
**Judgments.** — SUBJECT A: Something cold, 1 inch diam.; water on the hand (incorrect) (localized correctly). SUBJECT B: Something big, cool, spread out.
32. **Stimulus.** — Rectangular wooden surface,  $20 \times 11$  mm.  
**Judgments.** — SUBJECT A: A circular area, 1 inch diam. (localized correctly). SUBJECT B: Something like a small door-knob,  $1\frac{1}{2}$  inches diam.; slightly cool (localized correctly).
33. **Stimulus.** — Rectangular wooden surface,  $30 \times 11$  mm.  
**Judgments.** — SUBJECT A: Large indefinite area, nearly circular (localized correctly). SUBJECT B: (No experiment.)
34. **Stimulus.** — Rectangular wooden surface,  $50 \times 11$  mm.  
**Judgments.** — SUBJECT A: Elliptical; long axis = 2 inches; short axis = less than 1 inch; pressure (localized correctly). SUBJECT B: Big; elliptical; 3 inches long; soft (no sharp edges); slightly cool (location included area stimulated).



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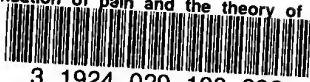






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